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INCENTIVES IN MANAGEMENT AND PRODUCTION

ALTHOUGH in his speech at the outset of the debate in March in the House of Commons on the economic situation in Great Britain, Sir Stafford Cripps emphasized the importance of the necessity for some incentive element, throughout the wages structure, which would be an inducement to a higher rate of productivity, and elaborated further the policy foreshadowed in the White Paper in that respect, the Budget proposals showed little evidence of the Government's intention to implement that policy. The debate on the economic situation tended to concentrate attention on this question of incentives, and on that of securing the most effective distribution of man-power. Mr. Lyttleton brought strong support to Sir Stafford Cripps' observations on the importance of incentives, and Wing-Commander Millington's example of the increase in output of bricklayers from 80 bricks to 462 bricks per man per day as a result of incentive schemes shows what can be done by the introduction of incentive schemes into wage systems.

The vital bearing of both these factors on the industrial and commercial efficiency, on which, as Sir Andrew Duncan rightly said, rising standards of living, increased leisure and social security all depend, was fully displayed in the debate, although the significance of the Prime Minister's remarks about mixed incentives was passed over. Doctrinaires on either side will do real harm by attempting to exclude either the public or private interest motives. Few men and women are not influenced both by the idea of public service and by private profit, and which incentive is the more effective will depend on circumstances, and on the type of person. What needs to be remembered is that the question of incentives is not restricted to one particular class : it is as important among the professional and managerial class of workers as among the manual workers. While, however, the importance of efficient management is now widely recognized, the question of management incentives has received nothing like its proper attention. It is fully as important as that of the wisest distribution of our resources in administrative ability, over which such concern was expressed in the House of Commons debate on man-power on March 19.

Taking the brain-power of Great Britain as a whole, we have to do two things. On one hand, we have to see that it is deployed to the best advantage —that neither the Armed Services nor the Civil Service are allowed to draw excessively on the limited resources of trained man-power, scientific or otherwise, leaving the universities each year, and that within the Services as in industry those resources are fruitfully and fully employed. On the other hand, we have to see that the conditions of service are such as to stimulate those men and women to exert to the utmost the abilities which they possess.

It is realized that the allocation of technical knowledge between the competing demands of

defence, industry, medical research, etc., is no simple task. Even a system of priorities demands constant scrutiny and revision, and only incessant vigilance can eliminate waste even if man-power has been allocated in accordance with the most rigorous and satisfactory scheme of priorities. Moreover, the debate on defence on March 20 gave rise to some uneasiness that in certain fields the distribution of trained man-power is out of balance.

In a speech in the defence debate on March 19, Mr. A. V. Alexander announced that during the coming year some £60 millions would be spent by the Admiralty and the Ministry of Supply in scientific research and development. He had already, in the debate on the economic situation in Britain, indicated that, of the man-power in the Armed Forces, some 46,000–47,000 were engaged in such work. The estimated expenditure of £3,118,000 of the Department of Scientific and Industrial Research includes some for military purposes, and the grants to universities and agricultural colleges and institutes include large sums for maintenance and teaching costs and the usual apparatus of student life; hence *The Economist* is probably not far wrong in its estimate that out of an anticipated expenditure of slightly less than £19 millions for research during 1947–48, including that on the Agricultural and Medical Research Councils, Colonial research, the universities, and research financed directly by the Department of Agriculture and Fisheries, only some £10 millions is used for research proper.

The contrast between this £10 millions and Mr. Alexander's £60 millions is striking, even when we bear in mind that the figures do not include the unknown but considerable expenditure of private industry on research. But whether the comparison is by expenditure or by man-power, the picture seems out of balance, and however readily it may be possible to justify the expenditure on military research—and the stress laid in the defence debates on the importance of scientific development and research is a welcome and reassuring feature—it at least appears probable that the economic position of Britain makes further assistance necessary from the Exchequer for research in fields bearing on industrial development. Mr. Alexander stated that the Defence Research Policy Committee and the Advisory Council on Scientific Policy would be in general control of policy and priorities, and would concentrate their energy on stimulating research in fundamentally new fields which scientific discoveries have opened up. On the picture thus presented, they will need to grapple more seriously with the distribution of the country's scientific man-power and material resources than the Government has yet attempted to do. It is at least a sound reason for Sir Henry Tizard's tenure of the chairmanship of both bodies.

The distribution or redistribution of man-power in any field is admittedly a difficult problem; but despite the attention focused upon it in recent debates, few constructive proposals have been forthcoming either from the Government or the Opposition. Reliance appears to be placed in the main upon incentives, and although the operation of a system of incentives either as a factor in attracting man-power or brain-power where the interests of the nation most require them, or in increasing output, is handicapped by shortages of raw materials, equipment and labour, the importance of incentives is not easily over-stressed. For all that, Mr. R. A. Butler appears to have been alone in the recent debate on the economic situation in stressing the importance of incentives for the management and others in industry as well as for the manual workers.

The point has not entirely escaped Political and Economical Planning, which in a recent broadsheet, "Men, Management and Machines", pointed out that first-class management will not be obtained while every manager is liable to indiscriminate political denigration. The psychological factors are in fact even more important than the financial incentives for the manager, and also for the research worker, and an interesting little note "The Requirements for Fruitful Research" printed in a recent issue of the *Journal of Chemical Education* (**24**, 165; 1947) is rather marred by its failure to recognize this. In this article a distinction is drawn between the worker in pure science and the worker in applied science, and the investigator in applied science is designated interpreter.

The distinction between pure and applied research is much less clear-cut than is suggested in this note, though it is rightly urged that the function of the applied research worker is "to deliver the goods", and that industry will judge his success by the measure in which his work leads to practical results. Few research managements, however, would to-day agree that adequate material rewards alone would suffice to attract the best men in adequate numbers. Individual rather than mass psychology is also important, and for fruitful industrial research the atmosphere and conditions of work are little less important than in fundamental research in the university. The atmosphere of freedom matters, too, even if there must in the nature of things be restraints that do not, and should not, apply in the university, where fundamental research finds its natural home.

What is overlooked in this little note is the interaction between the university and industry. If it is important that a university should rigidly guard its freedom and abstain from entering the field of applied research, it is equally important that conditions within the university and within industry should be such as to foster the free and full exchange both of staff and of knowledge. Neither will benefit from disparities in conditions of service, financial or otherwise, which denude one or the other of a proper proportion of the highest type of ability it needs. One of the greatest problems facing Great Britain is in fact to provide in industry and in the public service conditions which stimulate to the highest degree the creative thought, the enterprise and adventurousness which mark the ideal investigator at the university seeking to extend the bounds of human knowledge.

That indeed is the position taken up by Mr. W. B. Wiegand, director of research of the Columbian Carbon Co., in a paper, "Motivation in Research",

in *Chemical and Engineering News* of October 25, 1946. Mr. Wiegand emphasizes the complex character of motives or incentives in research, and observes that it is a mark of true insight to foster and encourage the adventurous phase of research. The competitive spirit, he holds, cannot be ignored, and need not be discouraged. Mr. Wiegand recognizes the value of a generous publication policy and of taking care to ensure that individual recognition is forthcoming for good work; but however careful we may be to establish the right conditions of service, the spark of leadership will always be indispensable for the most fruitful results. Motives and emotion are indivisible, and a friendly, loyal and appreciative management is as vital a factor in research as it is in the handling of men in production or distribution, and one which no elaborate equipment or careful organisation can displace. Indeed, the very fact that industrial research depends so much upon teamwork enhances the importance of leadership in this sense as contrasted with the direction of research.

The point was well brought out by Mr. L. C. Gabriel in his chairman's address to the Road and Building Materials Group of the Society of Chemical Industry last year. Industrial research must obviously conform to a long-term predetermined plan, and the leader of any research team must exercise mental discipline to ensure a proper relation between achievement and the agreed plan. Much latitude in detail must be allowed to all responsible staff, and the control from above must seek essentially to promote a voluntary discipline to prevent helpless drift and to turn individual enthusiasm into profitable channels.

Such psychological factors are more important than the physical conditions of work. This is not to deny that a research team works most fruitfully in a modern well-equipped laboratory, with pleasant surroundings, facilities for reading and writing and for formal and informal discussion, nor to suggest that there are not many industrial and indeed academic laboratories which fall far short of any reasonable standard in this respect. But it is well to remember that, in research as much as in industry at large, there is a factor of management or leadership which is indispensable to enable our objectives in research or in production to be attained; no organisation, on the national scale or in the laboratory itself, which disregards this factor can hope to succeed or to secure that higher standard of productivity and greater output upon which national recovery depends.

From this point of view the problem is similar whether we approach it from the aspect of labour or from that of research. The manager or administrator has to take account increasingly of the human factor and to devise the conditions of work and the incentives which will induce men and women willingly to give of their best. In so far as nationalization of an industry promotes such an atmosphere of co-operation—as is probably true in the coal industry—it is *a priori* to be welcomed, provided there are not other factors in nationalization which militate against efficiency. It must be borne in mind that so far there has been little evidence that the public corporation provides the conditions of service or the incentives which stimulate enterprise, initiative and first-class efficiency in the administrator in quite the same way as the best concerns in private industry.

It has already been suggested that this may well be our biggest problem. It is admittedly difficult and complex, but there are new opportunities opening up before us, and new instruments being created which may be used to find the way to a solution. It is one to which the National Coal Board may rightly be expected to give some consideration, and it is pre-eminently one for consideration and study by the new British Institute of Management and the Administrative Staff College. Other bodies too, such as the Institute of Industrial Administration and the National Institute of Industrial Psychology, have contributions to make, and the trade unions themselves could help if they were minded to take a more positive and constructive view of their functions. Bonus schemes and other financial incentives for the research worker and manager might well be re-examined objectively by such bodies; but much more is required. The creation of the right atmosphere and conditions of co-operation, and the discovery of the organisation and intelligence system which industry and society need to meet the increasingly complex demands of to-day, require co-operation from many quarters, and above all in the same spirit of impartial patient searching for truth which animates the research worker in his own laboratory investigations. Moreover, the growing importance, if not necessity, of a scientific approach to labour problems, as urged by Mr. W. C. Puckey in a stimulating paper before the Royal Society of Arts on January 29, with all that such an approach connotes, in training for management and in a scientific outlook on the part of the manager, emphasizes once more the necessity of a considered attempt to ensure that the administrator, no less than the research worker, is both adequately trained for his job and also given the essential conditions for doing it.

INDIA AS A SOCIAL KALEIDOSCOPE

Caste in India

Its Nature, Function and Origins. By Dr. J. H. Hutton. Pp. viii+279. (Cambridge: At the University Press, 1946.) 18*s*. net.

THIS 'brief conspectus' is for students, and assumes in its readers some knowledge of India and anthropology. Dr. Hutton claims no novelty, and draws freely on the accounts of Blunt and O'Malley (1931–32) and on his own Census Report of 1931, two important extracts from which, on 'untouchables' and on primitive religion, are reproduced *in extenso* as appendixes.

The ground is covered in three sections, each of four chapters. Part 1, "The Background", after a rapid glance at the races and languages of India, gives a short account, province by province, of such castes and tribes as illustrate the "almost incredible diversity" of Indian society. Part 2, "Caste", is

concerned with (1) "Structure", the interaction of marriage restraints and social status, and safeguards against *mésalliance*; (2) "Strictures" on food and drink, on custom and occupation; (3) "Sanctions", caste councils and other controls, the offences they try, their procedure, oaths, ordeals and penalties; (4) "Functions", the effect of caste for good or ill on the individual, the community, the State and society generally. Part 3, "Origins", discusses (1) institutions analogous to caste in other civilizations; (2) the traditional origins of caste in India (mostly from Chapters 6 and 12 of Dr. Hutton's Census Report of 1931); (3) theories of modern writers, and (4) conclusions drawn from the evidence.

All this is familiar; but the picture differs sharply from that drawn by nineteenth-century scholars, who, on the evidence of Sanskrit scriptures, traced caste (and civilization generally) to 'Aryan' invaders. But 'Aryan' culture as depicted in the Rigveda has little in common with Hinduism. Later research has revealed abundant evidence of elements typical of Hinduism in the pre-Vedic civilization of the Indus Valley cities and in the beliefs and practices of non-Aryan castes and tribes. The sources of Indian society and religion lie deeper and wider than the Sanskritists supposed. Presumably Rigvedic culture was absorbed into a strongly established indigenous culture of far older date.

The elaborate restrictions on marriage in India, the most prominent feature of the caste system, Dr. Hutton suggests may partly be due to "the impact of patrilineal invaders on an indigenous matrilineal population", and infers from good evidence that matrilineal descent, which still flourishes on the west coast, was at one time widely distributed throughout India. On these lines he would explain the prevalence of hypergamy, cross-cousin marriage, pre-puberty marriage, purdah and temple prostitutes.

Restraints on 'interdining', on the giving or taking of food and water, as well as pollution by touch, he ascribes to ideas of magic, mana, 'soul-stuff', life matter, etc., conveniently grouped as 'power' (p. 202), a sort of dangerous energy inherent in certain persons and things, the operation of which Sir James Frazer has aptly compared with that of electricity, which not so long ago was called a 'fluid'. Such taboos are common to all humanity, civilized as well as primitive; they have a practical value in a country where the population of a village may be decimated in a night by cholera, and vermin-borne disease may devastate the homes of 'untouchables', leaving their cleanlier high-caste neighbours unharmed.

Another big factor in shaping caste is the caste council. Each caste claims to discipline its own members. Brahman influence is indirect; Brahmans set standards of 'correct' behaviour and purity, and can withdraw their services in the ceremonies associated with birth, marriage and death in other communities, but they have no decisive authority in matters of caste. In early India such authority was vested in the king, and it still survives in many Indian principalities; but State jurisdiction is mainly appellate and adjusts disputes between caste and caste. The initiative in framing caste law and rules of conduct (*dharma*), the right to expel or re-admit, lie within the caste. The constitution and working of caste councils present every conceivable variety, and it is significant that the lower the caste in the social scale the stronger the organisation for regulating its own affairs, and it is strongest in tribes outside the pale of Hinduism. Obviously caste autonomy was neither invented by Brahmans nor imposed by State decree.

In assessing the merits of caste, Dr. Hutton stresses its value as a bond of union in a 'plural society', by which a multitude of disparate communities are welded into a social whole, yet retain each its own character and way of life; and he contrasts the 'stability' of caste from time immemorial with the warring nationalities of Europe and the colour problems of Africa and America.

Caste, in short, is an 'organic' growth, the product of many factors interacting within India over a long period of time, factors well known outside India; but, as Dr. Hutton observes in reviewing "analogous institutions", nowhere but in India do they produce a caste system. Moreover, like living organisms, the system is in perpetual flux, and has been so from time immemorial, constantly adjusting itself to changes in environment, ethical, economic, religious and so forth, new castes splitting off from old castes, and old castes rising or falling in the social scale; so mutable is it that no account of it can remain accurate for long. Criticizing not ungenerously the views of previous writers, Dr. Hutton deprecates approach from "a single view point", and makes no attempt to define the indefinable. Instead, he concludes with a list of the more obvious factors which have made caste what it is.

This compact essay should serve its purpose well. References are given in footnotes wherever needed; bibliography, glossary and index are excellent, and the student can thread his way easily through the haze of fact and fiction that surrounds caste.

F. J. RICHARDS

PRACTICAL FRUIT-GROWING

Fruit Growing Outdoors

By Raymond Bush. Pp. 518+105 plates. (London: Faber and Faber, Ltd., 1946.) 18*s*. net.

THE ready sale of Raymond Bush's Penguin Series of booklets on fruit-growing demonstrates the keen demand that exists to-day for sound advice on gardening topics, especially when presented in the easily assimilated form that characterizes the writings of Mr. Bush. The fact that here and there the expert can detect partial truths or inaccuracies detracts little from the general usefulness of the advice to the practical man, and provides the more knowledgeable man with opportunities for delighting himself in finding Mr. Bush at fault. No claim is made that the books are based on research findings, and it is obvious that they are not; but where it has suited the author he has made use of proved facts, and where it has not suited him, or where such facts are lacking, he has inserted his fancies with equal weight. Actually, his advice is very sound on the whole, as he is speaking about things with which he is thoroughly familiar after a lifetime of fruit-growing, for some years commercially and more recently as an amateur.

While the Penguin booklets are admirable for reading on a journey or carrying in the pocket, they lack the permanent binding and presentation that is needed for a book that will be used for constant reference. There can be no doubt, therefore, that the publication of these fruit-growing booklets in a single volume will meet with general approval. Messrs. Faber and Faber have made the thorough job that

one expects of them—clear, readable type nicely arranged on good paper, the whole being tastefully bound in a handy-sized volume, though more care in proof reading might have avoided the many small errors that occur in both text and index.

Reprinting of this nature, however, raises problems, some of which have not been very happily solved in this case. Two courses of action seem legitimate: either the separate parts reprinted in one volume should preserve the original matter intact, or if revision is permitted it should be thorough. While the first course is the simplest, the latter course has obvious advantages for the reader, and the scale of the present reprinting would have made such revision an easy matter. Mr. Bush has, however, adopted an intermediate course, making enough changes to lull the reader into a false feeling of up-to-dateness while leaving unaltered many other equally simple alterations. Thus, while "Lebensraum" becomes in a de-Nazified world "Elbowroom" (p. 337), and "Sir William Beveridge's" plans become "Socialist" ones (p. 222) with the change of Government, no reference is made of the valuable supplement to T. Wallace's "Diagnosis of Mineral Deficiencies" in the footnote on p. 94, where the original publication is mentioned. Reference is still made to a grafting booklet (p. 42), by R. J. Garner, that has been out of print for eighteen months or more, and the price is some three years out of date. The spraying chart remains untouched by recent knowledge, and stirrup pumps would seem to be still occasionally used for incendiary bombs (p. 183). The opening paragraph of Chapter 3 refers to the small space at the disposal of Mr. Bush in contrast to that in Mr. Bagenal's "Fruit-growing"; while this was true of one volume of the Penguin series, Mr. Bush's omnibus volume contains 496 pages in contrast to Mr. Bagenal's 416 pages!

The original illustrations have all been carefully re-drawn for this edition. The artist has made good use of the better facilities for reproduction afforded by this book, and the general effect is cleaner and neater. The result might have been better still if the artist had drawn direct from Nature instead of faithfully copying Mr. Bush, as he was not always quite correct in the original. For example, in Fig. 4 the bud looks quite unlike an apple bud, and the slit to accommodate it is inconveniently short. More care is needed in checking with the text those figures that have been altered; typical discrepancies occur with Figs. 64 and 65 and p. 362, where the footnote is no longer needed, Fig. 37 and description on p. 207, and p. 472 where the figure referred to does not appear.

The chief addition to the original volumes is the fine collection of plates. Few books of this nature are so well illustrated. Other valuable additions are line drawings of the chief insect pests, a section on renovating old trees, another on growing bush peaches and brief references to D.D.T. and the artificial setting of tomatoes. It is difficult to see why Section 3 was honoured by a re-written introduction when the fact that the original introduction was no longer suitable might have been seized on to omit it altogether, thus assisting the unification of the parts. It is surprising that it was considered necessary to number the chapters in parts since the pages are consecutively numbered right through, and the present arrangement leads to awkward cross-references in the text.

Considered as a handbook on fruit-growing, the arrangement could be much improved. It is disconcerting, for example, to find the subject of planning a fruit garden dealt with piecemeal in each of the three parts, with certain overlapping. The same is true of spraying. The chapter on books would be more appropriate at the end, and the important subject of spring frosts might have appeared nearer the beginning. The presence of chapters on nuts, mushrooms and tomatoes in the Soft Fruit Section seems scarcely justified. Naturally, one must accept this arrangement in an omnibus volume, but it is a pity Mr. Bush did not spare time to rearrange or rewrite the original Penguin booklets into a carefully planned manual covering the whole field of fruit-growing.

There is little doubt, however, that "Fruit Growing Outdoors" will find an honourable place on the bookshelves of keen amateurs, professional fruit-growers and even hardened research workers.

H. B. S. Montgomery

BREEDING OF FARM ANIMALS

The Breeding of Farm Animals

By Chapman Pincher. (Penguin Handbooks, PH.10.) Pp. 150+7 plates. (Harmondsworth and New York: Penguin Books, Ltd., 1946.) 1*s*. net.

ATTEMPTS at popular exposition of the scientific principles of farm livestock breeding have usually been made by those who have worked in one or other of the many fields of study which make up this 'practical' subject. No doubt, it is because of the intricacy of the considerations involved that the authors usually refrain from too sweeping or dogmatic statements, although they must recognize that their efforts to meet popular approval and appreciation are thereby weakened. Here, a fresh attempt to get some of the newer knowledge across to the practical man is made by an author whose name is hitherto unfamiliar in this particular connexion. Mr. Pincher brings his journalistic experience into action, and traverses reproduction, genetics, breeding policies, beliefs, and practical problems in pursuit of his objective.

He apologizes to professional biologists for certain conscious sacrifices to clarity in his treatment of the reproductive processes. But it must be confessed that this apology in itself raises doubts as to the origin of his lack of clarity and precision in other aspects of the general topic. His compilation of facts and his interpretations are open to criticism from men of science and practical men alike. As examples, from the many: few geneticists would agree that "The only test for the purity of a dominant character in a beast is to cross it with another animal known to be impure for that character", or that the F_2 ratio for a single pair of genes, with dominance, is 1 : 3 : 1; both groups of people would doubt the implication that true hermaphrodites are common in poultry flocks; and most sheep-breeders would object to the Black Welsh being included if the main breeds of mountain sheep were to be restricted to six.

The author has made a courageous attempt to expound principles usually considered applicable; but commendation is withheld for two main reasons. First, the numerous blemishes could easily have been removed without much effect on the content or the style of the book. Secondly, as at best such a text could only serve as an introduction to the subject, and not be entirely authoritative in itself, a general bibliography or selected references should have been given.

J. E. Nichols

SPONTANEOUS COMBUSTION OF HAY

By Dr. J. B. FIRTH and Dr. R. E. STUCKEY
Home Office Laboratory, Preston

THE self-heating of hay has long been a subject on which many conflicting theories have been put forward. Our recent work[1,2] has provided data which may perhaps help to give a clearer understanding of the processes preceding spontaneous combustion.

Early Theories

A number of the theories put forward were undoubtedly influenced by the prevailing chemical concept of the day. There were, for example, theories put forward dependent on the pyrophoric properties of certain elements, notably carbon, iron and manganese, when in a finely divided condition. Thus, Buckner[3] in 1872 introduced a theory centring about the idea of pyrophoric carbon and its absorptive power for atmospheric oxygen. Ranke[4] in 1873 made a detailed examination of a heated stack and was probably the first to describe hay which, when forked out, sparked and burst into flames. This phenomenon was held to support the pyrophoric carbon theory, and the attainment of the high temperature necessary for pyrophoric carbon formation was attributed to the insulating properties of the hay.

The stumbling block in these theories was the question of how the hay could arrive at such a high temperature, and to overcome this difficulty Miehe[5] (1907) put forward his low-temperature carbonization theory. In this it was assumed that the temperature was taken to 70° C. by thermophilic micro-organisms and never rose above 70°–80° C., a slow carbonization taking place. The interaction of the fine carbon produced and atmospheric oxygen caused the final ignition. This theory, however, has since been proved to be untenable, as James and Price[6] have reported fires due to spontaneous combustion which occurred in less than five days from the wetting (due to floods) of hay.

Boekhout and de Vries[7] considered that ionized iron in the cell sap had a catalytic action, while Laupper[8] held pyrophoric iron and not pyrophoric carbon to be responsible. The latter investigator worked out an extensive scheme showing products at various stages in a stack, introducing at the final stage pyrophoric manganese. There can be little doubt that in the later stages of the heating, pyrophoric carbon will be produced; but this is probably true of the prolonged heating at high temperatures, in the absence of air, of any similar organic material. The point is that the pyrophoric substances are only secondary in action and have no bearing on the main cause of the heating.

Another phase of theories was originated by Tschirch[9], who strongly criticized Miehe's low-temperature carbonization theory, advancing the view that not bacteria but oxidase enzymes were responsible, through production of oxygen which was 'pent up' and caused rapid oxidation and heat. Burri[10], modifying this, postulated heat-resisting enzymes, though later Hildebrandt[11] concluded from experiments that enzymes could not be responsible, and criticized the theory of Tschirch. Hildebrandt reverted to the assumption of the activity of micro-organisms as an explanation.

These theories are open to criticism mainly on the grounds that although certain experiments were carried out in their support, conclusions were drawn on evidence which was not related to the intermediate and end-products of self-heating actually present in a stack. This drawback probably originates in the difficulty of observing stacks which have undergone spontaneous combustion. Investigation of numerous stack fires during the war years (more than a hundred and fifty fires have been examined, including fifty samples of self-heated hay at all stages of development and heating) has given us opportunities of examining and trying to explain the processes occurring.

Certain fundamental facts are available on which any explanation can rely. Cohn[12] (1890) showed that approximately 40° C. was the highest temperature reached by means of ordinary plant respiration, but there was a further rise to 70° C., possibly due to thermophilic micro-organisms. Miehe (*loc. cit.*) isolated numerous organisms and named *B. calfactor* as being responsible. The work of Haldane and Makgill[13] also supplied evidence in support of this.

Browne's Theory

Browne[14] (1929), in an excellent review of the subject, made the first real attempt to put forward a logical explanation of the self-heating in the decomposition of substances by micro-organisms, followed by a chemical effect producing the breakdown of sugars in the presence of ammonia—a number of reports having mentioned the odour of ammonia around a stack.

According to this view, there was no difference in the mechanism of the heat production between 50° and 70° and above 70°, the heat being due in both cases purely to chemical causes. Browne states: "In other words the micro-organisms simply produce the highly unstable compounds whose subsequent oxidation . . . generates the increasing quantities of heat that lead first to the destruction of the organisms themselves and then eventually to the ignition of the hay". This theory was held to be supported by experiments showing the production of unstable unsaturated compounds from sugar by the action of lime.

Browne adds: ". . . the foregoing explanation of the spontaneous combustion of hay may be criticized on the grounds that there is no evidence for the existence of such highly unstable intermediary compounds as this hypothesis requires".

A New Approach

In our opinion the theory of Browne is essentially true. We have, however, never found a stack, heated or not, which was alkaline in reaction. All were slightly acid, and the spontaneously heated stacks very strongly so. Ammonia is probably present at some stages from protein breakdown; but we have not actually encountered it, and it is certainly not present to such an extent as to cause carbohydrate breakdown in alkaline medium.

Our preliminary work[1] showed certain features of a self-heated stack, chiefly (in a chemical sense) the gradual development of an acidity which was at a maximum in dark brown hay before such hay had reached the actual temperature of carbonization and destruction of products. Stacks showed in general two effects of spontaneous combustion; in one of these there was a large, central, heated portion with general conflagration and no visible 'flues'; in

another, the heated portions were more distinct and a number of 'flues' were shown which smoked and smouldered although the stack might not actually be burning.

Further work[2] on the chemical constitution of the acidity showed that the non-volatile fraction consisted of lactic, malic and succinic acids, while the volatile acids acetic and formic were also present. Lactic and acetic acids predominated. The total acidity was up to 8–9 per cent calculated as lactic acid on the dry matter, and a number of samples analysed later contained as much as 12 per cent. Since acetic acid, the main volatile acid, is present, it is very probable that the real acidity was much higher than actually found, volatile acid being lost in the heating process.

Considerable loss of volatile acidity is in fact unavoidable, and it is noteworthy that in cases where the stack was specially cut for us, and samples were taken from inside and immediately transferred to air-tight containers, the acidity was of a higher order and the volatile acidity proportionately greater.

It is obvious that the production of acidity is a big factor, and almost certainly the main factor, in self-heating, and that any satisfactory theory must take this into account. It is also clear the acidity is derived from carbohydrate breakdown.

The examination of the type of acidity gave, in our opinion, a very definite lead to the processes taking place. Typical results were as follows:

	1	2	3	4
Volatile acidity calculated as acetic acid percentage on dry hay	1·51	1·20	1·17	0·36
Residual acidity calculated as lactic acid percentage on dry hay	5·33	4·32	4·81	2·37

This shows good agreement with the acidity present in silage of higher acid values. Watson[15] quotes the following analysis of ordinary silage of varying *p*H values:

	1	2	3
Volatile acids calculated as acetic acid percentage on dry hay	3·21	2·91	4·01
Residual acidity calculated as lactic acid percentage on dry hay	8·44	4·33	2·60

Figures are rather variable, and obviously in such a complex and cumulative action as carbohydrate breakdown even a slight variation in conditions may lead to big variation in the resulting products.

The composition of the acidity of silage determined earlier by Annett and Russell[16] was remarkably similar to that found for self-heated hay. Thus, Annett and Russell found that the fixed acidity contained lactic, malic and succinic acids; the volatile acidity contained acetic and formic acids. The striking similarity between the composition of silage and self-heated hay indicated that a study of the processes occurring in silage would most probably provide the answer to the problem of the haystack.

In silage the crop is alive in the silo and for the first stage is actively respiring, aerobic changes taking place while the air in the herbage is used up. When this occurs, the second stage starts and intracellular respiration or fermentation takes place. The cells die, and micro-organisms begin to multiply, using as a medium the contents of the dead cells. The chief changes in the silo consist of the breakdown of the carbohydrates with the production of carbon dioxide, alcohol, and organic acids including acetic and lactic acids. Proteins are also broken down, though this may, perhaps, be an action secondary in importance so far as spontaneous heating is concerned. The exclusion of air, either partial or total, is necessary for the proper production and preservation of silage. The temperature of the mass usually rises, varying with the efficiency of exclusion of air.

In the silo, conditions are such that there is a plentiful supply of moisture but a limited and finally negligible amount of air. If air were admitted freely during the operation, a high temperature would result, and presumably spontaneous combustion would finally take place just as in the case of moist hay. In stack silage where exclusion of air is difficult, temperatures are high.

Suggested Actions Occurring in a Stack

In an ordinary well-made, well-dried haystack, there is a supply of air in the centre—not abundant, but sufficient. Some respiration occurs, the amount depending on the extent to which the drying process has killed the cells, and this is followed by the second stage, namely, microbiological action with the production of some breakdown products and acidity. This action is very slight in the ordinary, normal stack, but occurs further in the production of 'brown hay', popular on the Continent, with temperature rising often to 90° C., together with some caramelization of sugars. Fairly early, however, in a normal stack, a stage is reached when the amount of water is insufficient to allow further growth of micro-organisms, activity slows down and the stack cools off. Here *water* is the limiting factor preventing the continued growth of the micro-organisms.

In the case of hay which is undergoing spontaneous combustion, there is sufficient moisture present to allow further changes in the silage cycle, and the temperature rises rapidly if air is present to any extent (note that after flooding in Vermont, U.S.A., stacks 'fired' in four days). Carbohydrates are decomposed by micro-organisms to produce, for example, lactic and acetic acids from unstable intermediate oxidation and breakdown products. The porous structure of the hay helps in the process, and oxygen is absorbed from the air, oxidation occurring at points of molecular unsaturation with the production of heat. It is commonly known (cf., for example, J. Thompson[14]) and has been confirmed by us in the investigation of linseed oil-waste fires that the products of oxidation strongly catalyse the oxidation itself; that is, the process is autocatalytic. In addition, it is found that 40° C. is a critical point in the self-heating of waste contaminated with unsaturated oils. Above this temperature, spontaneous heating is much accelerated, and by raising the temperature to 40° C. combustion can be started in many materials which would otherwise not ignite.

Above 40° C., therefore, heat is being developed in the hay at an increasing rate. Towards 100° C., water is driven off to outer layers and we get a change, in that the reaction is taking place for the first time in comparatively dry medium. Earlier in the cycle, water was a limiting factor, curtailing the growth of micro-organisms; lack of oxygen now becomes the limiting factor until the decomposition, often following the path of hot gases produced, reaches the outside of the stack. There the excess of oxygen produces enough heat to cause fire.

The processes occurring in wet hay, ordinary normal hay and silage are summarized below.

Self-heated Hay.

(1) Respiration takes place causing the initial rise in temperature. The amount of respiration depends on the extent to which the plant cells have been killed in the drying process.

(2) Micro-organisms develop rapidly in the presence of moisture and with the rise in temperature, attacking the cell sap constituents and initiating decomposition.

(3) Rise in temperature up to c. 40° C. kills plant cells and respiration ceases. Some thermophilic micro-organisms may continue to be active above 40° C. Sufficient water and air are present to allow growth to continue. Breakdown of carbohydrates produces unsaturated compounds which are oxidized and partly hydrolysed with the production of heat.

(4) At temperatures above 40° C. the micro-organisms are gradually killed off by the temperature. *The decomposition products are then sufficient in amount to catalyse further decomposition of carbohydrates.* The increased temperature gives a greatly increased rate of oxidation of unsaturated compounds, as shown experimentally for unsaturated fatty oils.

(5) At 100° water is driven off from the heating centre, and oxidation and hydrolysis are replaced by oxidation with production of more heat. The limiting factor now is the amount of air present.

(6) The rate of chemical reaction increases sharply until the surrounding hay is charred and access to air is gained. Here, the plentiful supply of oxygen gives heat which cannot be conducted away, and ignition occurs.

Ordinary Hay.

(1) Some respiration takes place causing rise in temperature, the extent depending, as with self-heated hay, on the extent to which the plant cells have been killed in the drying process.

(2) Micro-organisms develop with rise in temperature, attacking cell constituents. Decomposition is slight, *the growth of the organisms being limited by the lack of water.*

(3) Decomposition is insufficient to set up the autocatalytic reactions, and the stack cools off.

Silage.

(1) Respiration takes place until all oxygen is used up or replaced by carbon dioxide.

(2) Micro-organisms develop and operate in the absence of air. The limiting factor here is the lack of air, and the interior of the silo cools off. Breakdown products of carbohydrates are produced; but there is insufficient air for any extensive oxidation to take place, and the heat developed is small in comparison with wet hay.

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THE CULTIVATION OF A THERMODYNAMIC OUTLOOK

THE place of thermodynamics in education was recently discussed by the Low-Temperature Group of the Physical Society. In outlining the purpose of the discussion, the chairman, Sir Alfred Egerton, explained that a feeling exists among members of the Group that the thermodynamics teaching given to students in Great Britain is often inadequate; and it was in the hope of formulating constructive proposals for its improvement that this meeting was called. He added that it was not his intention to confine discussion only to low-temperature aspects of thermodynamics, but to encourage discussion over the whole thermodynamic field.

Opening the discussion, Sir Charles Darwin pointed out the difference between the teaching of mechanics and of thermodynamics in Britain. On one hand, in the teaching of mechanics, the student is drilled to solve numerous examples until all the implications of Newton's Laws have been driven home. On the other hand, thermodynamics is often introduced in abstract terms and clothed in a maze of algebraic symbols, thereby leaving the student confused in his conception of the subject and ill-equipped to apply such thermodynamic knowledge as he has gained to new problems. Sir Charles thinks thermodynamics is a harder subject than mechanics, but not much harder.

Elementary teaching of thermodynamics in the past has been confined almost entirely to gases and liquids, and this has tended to obscure the generality of the subject. Also in setting examination questions too much demand has been made for the mathematical manipulations involved in getting, for example, from C_p to C_v. Now that the new fields of magnetism and the elasticity of rubber have been opened, other examples are available, and the teaching of thermodynamics can be widened in its outlook. Exercises in spotting the fallacies in perpetual motion machines also provide a useful field of instruction. The use of numerical examples should be extended, for only so can experience be gained of the relative importance of the various factors in a process.

In conclusion, Sir Charles Darwin posed three questions, to which he supplied his own tentative answers:

(1) Should thermodynamics play a greater part in education?

(2) At what stage, school or university, should it begin?

(3) Should statistical theory come in?

To the first question he gave an affirmative answer. In answer to the second question he considers that a start should be made at school about two years after mechanics, but to be suitable for schools the text-books will need to be re-shaped. Regarding the third question, he favours withholding statistical theory, except for a few descriptive examples which call for no mathematics.

The next speaker, Prof. E. A. Guggenheim, stated his convictions that the number of people in the world who thoroughly understand thermodynamics in all its aspects is well under a hundred, and the number in Great Britain is certainly in single figures. He said, however, that he is less disturbed by these small numbers than by the degree of ignorance of

thermodynamics by the remainder of physicists, chemists and engineers. Unfortunately, this includes people whose task it is to teach thermodynamics and to abstract papers on this subject. A symptom and, at the same time, a cause of this state of affairs is the failure to afford to thermodynamics its true significance and status by confusing it with the experimental techniques of thermometry and calorimetry, and the largely empirical laws of heat transfer, under the general title of 'Heat'.

Thermodynamics, he said, has a bearing on almost every branch of physics and particularly on mechanics, hydrodynamics, electrostatics, capillarity and chemistry. In these subjects many of the laws and formulæ taught are defined only under the condition of constant temperature—for example, Hooke's Law, Ohm's Law and Boyle's Law. As soon as one inquires into the effects of varying the temperature, one enters the domain of thermodynamics. This has led to much confusion in the use of the word 'energy' in such expressions as the 'energy of a coiled spring', or the 'energy of a charged condenser'. Here the quantity cited is usually the free energy, and the total energy is a more complicated quantity, since it is to be noticed that the performance of work at constant temperature is, in general, accompanied by a simultaneous absorption or emission of heat.

Prof. Guggenheim recommended that students, immediately after learning mechanics, should be made familiar with :

(1) the existence of temperature ;
(2) the conservation of energy ;
(3) the correct definition of heat ; and
(4) the distinction between actual and reversible processes.

The quantitative relationships between work and heat can best be introduced in particular examples, such as coiled springs, compressed fluids and charged condensers, as these subjects in turn come up. Only at a later stage is it necessary to stress that all such relations are particular examples of the general laws of thermodynamics.

Prof. D. M. Newitt, speaking of the bearing of thermodynamics on chemical engineering, stated that the aim of chemical engineering is to co-ordinate a series of elementary physical operations and chemical processes in such a way as to bring about economically some desired change of state or composition in a given system. It therefore requires equally a knowledge of thermodynamics and molecular physics. He considers it desirable that the teaching of statistical mechanics and the kinetic theory should run parallel with and not follow a course in thermodynamics since, in general, chemical engineering problems are concerned not only with the driving force necessary to bring about a specified change, but also with the rate at which that change can be made to take place.

Attention was directed by Prof. Newitt to the present unfortunate divergence, both of approach and of emphasis, in the teaching of thermodynamics to physical chemists on one hand, and engineers on the other. Thus the chemical engineer, who receives tuition in both schools, is liable to unnecessary confusion. The wide variation of notation between different text-books of both subjects has also added to the confusion. Prof. Newitt voiced the plea that uniformity of notation should be adopted in the teaching of thermodynamics. In conclusion, he suggested that more use might be made of graphical and geometrical representation in the teaching of thermodynamics. Exercises in the construction of such diagrams and models might well make up for the paucity of laboratory experiments for illustrating thermodynamic principles.

Mr. A. M. Clark said that, although a complete knowledge of thermodynamics may be restricted to a few, an understanding of the principles involved is important for all scientific workers, irrespective of the particular branch of the subject chosen for specialization. He considers that the first and second laws of thermodynamics are even more fundamental and more rigid than the basic laws of chemistry and mechanics, such as the laws of conservation of mass and Newton's Laws of Motion. The student should be introduced to them at the earliest possible stage, that is to say, at the same time as he learns to appreciate the other fundamental laws. For this purpose the early teaching of thermodynamics should be divested of advanced mathematics and complex nomenclature. Illustrations of the principles of irreversibility can be found in many simple processes. Yet fallacies are often encountered in scientific papers published in reputable journals, showing that these principles are imperfectly understood, even by some who aim at instructing others.

The next speaker, Prof. F. E. Simon, advocated that the first introduction to thermodynamics should be at school ; only so would the second law be quickly mastered. Moreover, this should be done even if it necessitates sacrificing some of the more tedious parts of physics. He lamented the present inadequacy of elementary thermodynamic text-books, and while commending Ewing's book, he considers the engineer's approach far too restricted. In teaching thermodynamics he considers the use of complicated systems and involved mathematical derivations inadvisable. The main difficulty experienced by students is in grasping the fundamental ideas implied by the thermodynamic laws, and the best way of elucidating them is by the use of numerous examples. In this connexion he considers the heat pump as one of the best illustrations for bringing home to students the significance of the second law.

Speaking as a physical chemist, Mr. C. R. Bury claimed that the modern precise thermodynamics is of little use in meeting practical problems. The work of Van t' Hoff gave us a method that is easy to apply, but the answer is unreliable. The modern thermodynamics is only useful with very simple systems, and as soon as a problem occurs requiring high pressures, mixtures, or solutions, the information is so scanty that the methods are useless.

Dr. K. Mendelssohn emphasized that in teaching thermodynamics the primary need is to explain what the subject is about and not to plunge into a mass of symbols. A study of the phenomena occurring at the transition from the superconductive to the non-superconductive state affords useful instruction.

Dr. M. Ruhemann disagreed with Sir Charles Darwin that Newton's laws are more readily understood than the laws of thermodynamics. He personally has found Newton's second law more difficult to understand than the second law of thermodynamics. He agreed with other speakers that thermodynamics should be introduced at school, and he considers that by embodying it in examples such as internal combustion engines and fuels it could be made interesting to these ages. He commended warmly the text-book by Boznjakovič and expressed regret that it is not available in English.

Dr. N. Kurti directed attention to the fact that in many universities there are several parallel and simultaneous courses in thermodynamics for chemists, physicists and engineers. If, instead, a combined course of lectures was given with emphasis on the nature and scope of the subject, considerable benefit would result. Mr. J. H. Awbery added to Dr. Ruhemann's contention, that the laws of thermodynamics are no more difficult than those of Newton, the point that students at school are drilled in mechanics at an age before they can ask questions, and it is solely this discipline which makes mechanics seem far easier. If thermodynamics was hammered home at an early age with plenty of illustrations, the concept of free energy would be as easy to understand as volume or temperature. Dr. L. R. G. Treloar also agreed with this point, stating that thermodynamics should be taught as dogma. Only so will familiarity and confidence be attained.

Summarizing the discussion, Sir Alfred Egerton indicated several points on which agreement had been reached. First, elementary instruction in thermodynamics should be given at school, and for this a very carefully prepared syllabus would be required. Secondly, in teaching thermodynamics more use should be made of diagrams and solid models; and thirdly, a unified system of notation is desirable. In conclusion, he pointed out that in 1850 Clausius and Kelvin had simultaneously, though independently, formulated the Second Law of Thermodynamics, and he expressed the hope that in 1950 the centenary would be suitably celebrated.

G. G. HASELDEN

NATURAL SCIENCE AND THE FINE ARTS*

By F. IAN G. RAWLINS
Scientific Adviser, National Gallery

I PROPOSE to consider here the relations which we may expect to find existing between these two great examples of human endeavour. In so doing it will be seen that the man of science, using that term in the broad sense, has been instrumental both in the fashioning of objects of art and in caring for them afterwards. It appears likely that many of the great masters of classical art were somewhat casual in their concern, as judged by our standards, for the beautiful things which they made; nowadays conservation has become an art in itself, and the philosophers are not slow in pointing out that our preoccupation with the treasures of the past may be bound up with a certain lack of confidence in ourselves to generate loveliness in our own time. However that may be, there is much to be said for a close study of the techniques of the great masters, and such a discipline does, in fact, help us to devise ways and means of looking after our heritage more adequately.

Thus, the man of science needs to be something of a *Kunstforscher* as well as competent to apply any method or methods which will help forward objective investigations of structure and condition. Clearly, one should know a good deal about materials and their limitations, above all to be imbued through and through with a sense of 'safety first', if museums and galleries are to reap positive advantages from the possession of a laboratory and its equipment. The war years, too, have provided problems on a scale commonly associated with those in engineering.

The greater part of this discourse will be devoted to the physics of classical paintings, chiefly because I find myself rather less incompetent perhaps with them than with other material; and secondly on the score of their combined weight and fragility, which makes them probably the most intractable of all. From the technical point of view they fascinate, not merely artistically, but because they are frequently so 'awkward'. At the National Gallery, for example, we have pictures weighing anything from a few ounces to nearly three quarters of a ton. To design plant both convenient and safe for such a range is not too easy. In surface area as well there is wide variation, from about 20 square inches to 16,000 square inches. The apparatus in question consists essentially of X-ray, ultra-violet and infra-red sources of radiation, with appropriate recording gear, both photographic and visual. In addition, there is considerable scope for colorimetry and for microscopy in polarized light. Further, the orthodox methods of photography have been extended to include macrographs, the use of special filtration processes, and the employment of raking light. In all this, one is not looking for the production of something that looks like the picture; we are seeking information which, in general, can only be obtained in bits and pieces, here a little and there a little, by deliberate exaggeration or suppression as the case may be. It is only when a purposeful effort at integration is made that the significance of these separate approaches becomes apparent. No method is known which by itself will tell us all that we wish to know, and unfortunately there are many examples in which failure occurs in spite of everything.

Here perhaps is the place to emphasize that scientific practice and methodology will never be substitutes for stylistic knowledge and insight. A certain amount of harm has occasionally been done to the cause of laboratory co-operation by expecting it to achieve results of which it is *a priori* incapable. Nevertheless, its help in confirmation, and briefly, in lifting conclusions out of the region of subjective judgment, has been demonstrated time and again. This only amounts to asserting the obvious truth that the nature of evidence needs extremely careful thought when using such evidence under conditions wherein the original assumptions cannot well possess full formal validity. Maybe this is why, in matters of this kind, there has been much reasoning by analogy, that is, from particular to particular. Scientific method will strive to raise this one degree in the hierarchy by attempting to apply the process of induction (that is, reasoning from the particular to the general); so far as one can see, it seems most unlikely that the final, or deductive, system will ever be reached in scholarship of the type we are contemplating now, since argument from the general to the particular is almost a denial of the individualism of art. It is a fact, however, that a remarkable degree of agreement is often registered among people thoroughly conversant with questions of style, iconography and provenance, but this is not to say that objective testing has no place in these deliberations. Its verdict *may* be crucial.

My purpose thus far in sketching, necessarily briefly, the theoretical background of the scientific-artistic complex has been to try to elucidate certain basic suppositions which experience shows to be liable to misapprehension or even to neglect. It is

* Substance of a Friday evening discourse delivered at the Royal Institution on February 14.

easy to claim too much; equally faint-hearted is it not to realize the force of analytic and synthetic means as signposts on the journey. With these dispositions in mind, we can tackle the experimental problems which await us with greater confidence. To some extent, our advances must be by comparative methods, that is by the use of models, since obviously no risks can be run with irreplaceable originals.

We now discuss in some detail the physical structure of a typical painting in oil or in tempera. Its most marked characteristic is its stratified nature; that is, it is built up of a number of layers. These are, starting from the back: (1) the support; (2) the ground; (3) the paint film; (4) the surface film. The physical boundary lies between (1) and {(2), (3), (4)}, since the support is essentially—for our present purpose—composed of a biological fibre (wood or canvas, or both), whereas the three superincumbent members are film-substances, differing mainly in the amount of pigment and medium which they contain. They are traditionally enumerated separately more on account of their method of application and purpose than for their differing chemical natures.

At the moment, however, I propose to consider particularly (3), for the paint film *is* the picture as commonly conceived. It is the design itself, and upon it, essentially, the æsthetic value of the whole depends. In many cases the paint film is itself complex, consisting of a number of components. These often show a lack of continuity in one plane, a rough parallel with the 'faults' of the geologist. Again, imbrication is not uncommon, which adds many a trap for him who has forgotten to walk like Agag. In general, interpretation of structure is difficult, by whatever means it is attempted.

Within the paint film itself (that is, restricting ourselves to one plane), we are confronted with a sequence or gradation of properties depending in the main upon the relative properties of pigment and medium. Paint structures rich in pigment are called *granular* (examples are to be found in most fresco and wall paintings); those of medium concentration are known as *vehicular* (a large class containing most normal easel paintings); and finally, phases very rich in medium are termed *pellicular*. In this latter group are found the glazes and, in the limit, pure oil films. The important point to notice about this scheme, which is due largely to G. L. Stout of Harvard University, is that whereas chemically all these entities are simply so much paint, the ordinary appearance depends mostly upon the state of aggregation, while the physical properties such as transmission, reflectivity, permeability and so on show correspondingly transitional characters.

From the point of view of the impact of electromagnetic radiations, however, we are concerned more particularly with the chemical nature of the pigment particles themselves. Thus, as is well known, lead in any of its numerous compounds is very opaque to X-rays, and so, of course, are the other heavy elements. It is for this reason that our X-radiographs of a picture represent a kind of scaffolding of the 'edifice', delineated into areas of high lead content. Ultra-violet tests, on the other hand, function because of the capacity of certain pigments to excite fluorescence, an effect which is not independent of the medium, whereas discoloured varnish is often reasonably transparent to the near infra-red. Naturally, a complete examination will include all these methods, and, as indicated earlier, no one of them alone is likely to tell the whole story. In general, each has its particular part to play.

At the risk of falling into the sin of over-simplification, I should mention that there are two ways in which an artist may build up his structure. One is to allow the ground, that is, No. 2 of the strata already mentioned, to provide the body of the lighter parts of the composition, adding white lead, perhaps very thin, for the high lights. Franciabigio's Portrait is an example. Alternatively, the whole of the lighter areas, including the high lights, can be painted in lead, beginning, of course, with a dark, or darkish, background. A head by van Dyck shows this technique well. Actually it is unlikely that a specimen can be produced to give a complete case of either practice; most instances are mixtures of both, inclining perhaps more one way than the other. But the conception is a useful one for technical purposes, and X-rays are capable, in general, of exhibiting these distinctions satisfactorily. All the layers, unfortunately, except those which are exceedingly thin, are registered together, which makes interpretation all the more difficult and at times uncertain. By reducing the penetrating power of the rays, gradation is much improved. We use 14 kV. or 21 kV., with a current of 15 ma. at the National Gallery, and are planning to go to still lower potentials. Exposure times are from two to three minutes, depending, of course, upon the thickness and nature of the support, as well as upon the type of ground and paint film. Good results may be expected if the ground is of *Gesso* (plaster of Paris), but not if a lead priming is present, or if a lead-bearing adhesive has been used in the course of relining. Radiography is defeated in these cases.

The ultra-violet is occasionally a very powerful weapon in a museum laboratory. So far as paintings are concerned, it is possible to reveal retouchings and to observe to what extent the surface film is intact. A characteristic fluorescence is excited. It follows that if it is desired to study the paint film in this way, it is essential to remove the varnish, the fluorescence from which is usually intense enough to obliterate everything else. In general, the ultra-violet is a means of dealing with surface phenomena, the penetration being nearly zero. At the other end of the wave-length scale we have infra-red radiation. Certain practical difficulties are commonly encountered, but the method has great possibilities, greater perhaps than those of X-rays. The reason for this is that, with orthodox X-ray equipment, as already mentioned, superposition effects cannot be avoided, whereas, naturally, they do not occur with a reflexion phenomenon such as infra-red photography. Thus varnish, even when highly discoloured, is usually penetrable; and if this is the case, a much improved image of the paint film is obtained compared with an ordinary photograph. At their best, infra-red records can be very significant, particularly for such masters as Tura, Crivelli, and Cossa, where exceptional under-modelling is brought out, and their anatomical build-up displayed. From ordinary vision, most of this is hidden.

It has probably become clear that much of what I have been saying so far is applicable *mutatis mutandis* to a variety of museum material other than paintings. Instrumentation will be a little different, and probably there will be greater scope for chemical investigations. The ultra-violet has not infrequently proved effective in the detailed study of pottery, and,

as is well known, for the elucidation of manuscripts and drawings. An ingenious application of electro-endosmose has been for the cleaning of pottery, of which the surface has become encrusted with salt crystals in which some pigment is entangled. The homely method of a good scrub with water would quickly end in disaster, since the precious coloured particles would be scattered far and wide by such treatment. But by immersing the vase in water, and inserting a cathode wire into it as one electrode, and using another wire dipping into the water as the anode, the salt crystals conveniently move off in one direction, whereas the pigment grains are drawn back on to the surface of the vase, to which they can then be anchored by the application of shellac; 30 volts D.C. for about half an hour is enough.

Another striking example of laboratory technique has been the mounting of Foraminifera from the limestone supports of classical fresco murals by means of thermo-plastic resins. Micro-sections can be made in this way from such friable material and preserved for archæological research in a convenient and permanent form.

At the beginning I referred briefly to the task of conservation in general. This is a matter which concerns the man of science very closely; and given the requisite knowledge for, and appreciation of, the task, he should be able to render valuable assistance. The experience gained during the War has been, or is being, turned to good account, and will assuredly influence future practice in gallery construction. With regard to the all-important subject of air-conditioning, it is essential to realize that any scheme must provide not only an appropriate environment for the exhibits, but also for the public. Repository surroundings during the war years can scarcely be considered as sure guides, since their only purpose was to take care of the valuables: the comfort and convenience of visitors did not arise. In short, we are now faced with a much more complex problem. Luckily, as regards relative humidity—the most vital single factor from the technical point of view—the human body is remarkably accommodating, much more so than with respect to temperature. Therefore we can provide a range of moisture-content well suited to the particular material, without the introduction of disagreeable features on that account. More trouble is likely to be met with in Britain in dealing with buildings architecturally unsuitable (as many are), and on account of our erratic climate.

In very general terms, the aim should be to prevent, or at least to diminish, the 'working' of substances like wood, textiles and so forth; or in the language of physics, to restrict the area of the hysteresis loop for wetting and drying to a minimum. This means keeping the moisture-content nearly level, which in its turn indicates the need for a constant relative humidity—say around 60 per cent for most exhibits.

More attention than hitherto will need to be paid to the so-called 'near-surface' effects. In other words, the relative humidity in the centre of a large room is not the same, even in the absence of temperature gradients, as that near the surface of objects placed in it. The reasons for this are complicated, but they point to the necessity of micro-determinations if trustworthy data are to be obtained for precious things, even if they are immersed in a nearly infinite reservoir of air of statistically satisfactory thermodynamic properties.

Given a return to something remotely approaching normality, there are good opportunities in the museum world: openings are not numerous, but they offer interesting careers with plenty of responsibility and scope for originality. But all on one condition. Natural science in such a context is ancillary to the fine arts in the literal sense of the word. She is art's serving maid; yet art must be sympathetic, apt to realize not only what science can do, but also what an objective philosophy can teach. Then all will be well. Such is our intention; and striving to attain it, not weighing our merits, but pardoning our offences, is, I take it, no more than our bounden duty and service.

OBITUARY

Dr. H. M. Tory

HENRY MARSHALL TORY died in Ottawa, Canada, on February 8, at the age of eighty-three. At the time of his last illness he was president of Carleton College, a post which he had filled from 1942 when he was instrumental in founding this institution of higher learning. At that time he had returned to active academic work after having enjoyed a few years of well-earned rest following a long life of high achievements. Thus once again his great talents for organisation were directed towards the establishment of yet another college. Early in his career he had contributed in no small measure to the founding of the University of British Columbia at Vancouver, and later the University of Alberta at Edmonton. He had directed the organisation of "Khaki College" in the First World War, and had been the first full-time president of the National Research Council of Canada. By virtue of his many high offices and as he was by natural bent a philosopher and an earnest educationist, he was widely recognized as one of Canada's most distinguished sons.

Born in Guysboro, Nova Scotia, on January 11, 1864, Tory was educated in the local academy and at McGill University, Montreal, where he graduated, a gold medallist in mathematics and physics, in 1890, and then continued on the staff as lecturer and associate professor, teaching mathematics and physics, and gaining a master's degree in 1896, and a doctorate in science, 1903.

From 1908 until 1928 he was president of the University of Alberta. His successors in office at that western institution have paid moving tributes to Dr. Tory's memory. Dr. R. C. Wallace, who succeeded him and is now principal of Queen's University, said: "He was a stalwart in the cause of world peace and intellectual co-operation, an able exponent of science in the modern world, and a warm friend to distressed peoples everywhere. There are not many men of Dr. Tory's stature in a generation, for he built the things that will endure"; and Dr. Robert Newton, president of the University of Alberta, expressed the feelings of many when he observed: "Dr. Tory was the greatest Canadian figure of his time in the field of education and scientific research".

Always actively interested in all matters concerning the welfare and progress of the Dominion and its people, Dr. Tory found himself chosen time and again to serve on royal commissions and boards established by various authorities to inquire into such diverse subjects as agricultural credits in Europe (1913) and in Canada (1923–24); coal classification (1923–35); the fruit industry in Nova Scotia (1930); and

the coal industry (1936). He was a special commissioner from Canada to the Pan-Pacific Science Congress in Japan, 1926, and it was largely through his efforts that Government authorization was secured for the holding of the Fifth Pacific Science Congress in Canada in 1933. He organised the Congress and served as its president (1930–34). He served as colonel-director of educational services for the Canadian Overseas Forces during 1917–19.

His outstanding qualities as an educationist and leader in science and culture were recognized repeatedly by the award of honorary degrees and other distinctions. He received the honorary doctorate in laws from St. Francis Xavier College in 1906; from McGill in 1908; University of Toronto, 1927; Saskatchewan, 1928; Alberta, 1928; McMaster, 1932; British Columbia, 1932; Western Ontario, 1933; and a doctorate in civil law from Acadia, 1935. He was Governors' fellow of McGill University during 1905–8 and non-resident fellow 1908–15.

A fellow of the Royal Society of Canada, Dr. Tory held office as chairman of the physico-chemical section in 1927 and as president of the Society in 1940. He was a fellow of the Royal Historical Society and had a deep and abiding interest in history, in which subject he lectured at the University of Alberta. He was more especially interested in the history of philosophy and science, and conducted classes in these subjects at Carleton College. The Tory collection in the National Research Library was founded by his friends to commemorate his interest in this field of study.

In February 1923, Dr. Tory was appointed a member of the honorary advisory Committee for Scientific and Industrial Research, and named as chairman in October of the same year. He became director of the laboratories at Ottawa when these were still housed in temporary quarters, and president of the Council in 1927. Under his presidency, construction of the National Research Building was undertaken in 1930. He personally directed the planning of this fine structure, which was opened by Mr. Stanley (now Lord) Baldwin, at the time of the Imperial Economic Conference in Canada, 1932. Before he retired from the presidency of the Council in 1935, he had selected the original staffs for the laboratories and established the standards of ability and performance which enabled the institution to meet the challenge of war as it did.

Those with an intimate knowledge of Dr. Tory's work as president of the National Research Council will feel that his contributions to organised scientific and industrial research in Canada, which are acknowledged to-day, will loom larger still as the years lend perspective to the progress which Canada is making in this field. "An example and an inspiration, this man of the deepest integrity and the fullest public spirit will not soon be forgotten by the generation he served so admirably and so efficiently."

C. J. MACKENZIE

NEWS and VIEWS

Royal Society: New Foreign Members

THE following have been elected foreign members of the Royal Society:

DR. E. J. CARTAN, professor of geometry in the University of Paris and member of the Paris Academy of Sciences, distinguished for his fundamental work in the theory of continuous groups and in differential geometry;

PROF. P. KARRER, professor of chemistry in the University of Zurich, distinguished for his outstanding contributions to the chemistry of natural products, with special reference to the chemistry of the carotenoids, carbohydrates and vitamins;

PROF. H. C. UREY, professor of chemistry and director of the Institute for Nuclear Studies, University of Chicago, distinguished for his discovery of deuterium, for his investigations into the separation and properties of isotopes, and for the application of these discoveries in the development of methods for producing atomic energy;

DR. ØJVIND WINGE, of the Carlsberg Laboratory, Copenhagen, distinguished for his many fundamental contributions to the cytogenetics of plants and animals.

Royal Naval Scientific Service: Sir Charles Wright, K.C.B., O.B.E.

CHARLES SEYMOUR WRIGHT, who has just resigned from the post of chief of the Royal Naval Scientific Service, was born in Toronto in 1887. He was educated at Upper Canada College and the University of Toronto. He won a Wollaston Research Studentship and an 1851 Exhibition Scholarship, with which he proceeded to Gonville and Caius College, Cambridge. He did research work at the Cavendish Laboratory during 1908–10. He joined Captain Scott as scientist to the Antarctic Expedition, 1910–13. After the return of the survivors of this expedition, he spent a year at Cambridge until the outbreak of war. He joined the Royal Engineers in 1914, first as wireless officer to the 5th Corps, during which period he earned the Military Cross. He later became O.C. Wireless of the 2nd Army, and for his services at this time was made a Chevalier of the Legion of Honour. He was decorated with the O.B.E. for his subsequent work in the Intelligence Division of the General Staff.

After he had been demobilized, he became senior assistant to Mr. F. E. (later Sir Frank) Smith, then director of the newly formed Department of Scientific Research and Experiment at the Admiralty. In the same service he was appointed superintendent of the Admiralty Research Laboratory, Teddington, in 1929, a post which he held for five years. He became director of scientific research at the Admiralty in 1934 and carried throughout the Second World War the high responsibilities of this director's position as well as during the rearmament period preceding it. With the formation of the Royal Naval Scientific Service in 1946 and the reorganisation of Admiralty arrangements for the direction of scientific research, he was appointed first chief of the Service. He was made a C.B. in 1937 and a K.C.B. in 1946. All who served under him received help and guidance from a most genial personality. He will be greatly missed by his colleagues and by the scientific workers with whom he came in contact elsewhere.

Mr. F. Brundrett, C.B.

THE Admiralty has announced that Mr. F. Brundrett has been appointed chief of the Royal Naval Scientific Service in succession to Sir Charles

Wright. Mr. Brundrett went to Sidney Sussex College, Cambridge, and obtained first-class honours (Wrangler) in the Mathematical Tripos. During 1916–19 he served in the R.N.V.R., and then was appointed to the scientific staff of H.M. Signal School, where he served in various capacities until 1937, his most outstanding original technical work being on the propagation of short wireless waves and in the organisation of world-wide propagation trials. In 1937 he was transferred to the Scientific Research and Experiment Department, Admiralty, as principal scientific officer, where a sequence of rapid promotions led to his becoming a deputy director of scientific research in 1942. In 1946 Mr. Brundrett was appointed assistant to the chief of the Royal Naval Scientific Service for the reconstruction period.

At the start of the Second World War, as many hundreds of scientific men throughout Great Britain will know from personal experience, Mr. Brundrett accomplished with great success a prodigious task in organising and recruiting a vast expansion of the Navy's scientific staff, and in the radar research branches of the other Services. He was throughout the War particularly prominent in the organisation and administration of radio valve research for the Services. He was honoured with the award of the C.B., in recognition of his war-time work, in the New Year Honours, 1946. Mr. Brundrett has a farm in Hampshire where he has achieved great success in the breeding of pedigree poultry and Red Poll cattle.

Physics at King's College, London: Prof. C. A. Coulson

Dr. C. A. Coulson, recently appointed to the University chair of theoretical physics at King's College, London, is among the foremost workers in Great Britain on the wave-mechanical side of quantum theory. Although Coulson's research papers cover a very wide range of interests (he collaborated with Lea and Haines in early work on the action of radiation on bacteria and has also made contributions to the theory of liquids and solutions), the great bulk of his published work deals with the application of wave-mechanics to the theory of molecular structure. It has been concerned both with the determination of accurate wave-functions for simple molecules and molecular ions and with the necessarily more approximate treatment of large organic molecules. An extensive series of papers in collaboration with W. E. Duncanson deals with the rather neglected field of momentum distribution functions and the related Compton-line profiles.

In the theoretical treatment of large unsaturated molecules, Coulson uses the method of molecular-orbitals originally due to Hückel and first developed in Britain by Prof. (now Sir John) Lennard-Jones at Cambridge. Coulson has used this method for a great variety of problems, from the computation of the bond-lengths of such a molecule as coronene to a calculation of the electrical conductivity of pure graphite. Recently, at Oxford, Coulson and his co-workers have made considerable advances towards an understanding of the effects of substituents in molecules and a general theory of chemical reactivity. In addition to his research papers, Dr. Coulson has also written text-books on the more elementary and classical aspects of mathematical physics. He has a well-deserved reputation for his kindly and helpful encouragement of younger research workers.

Food and Agriculture Organisation: Production and Research

Dr. G. Scott Robertson, Permanent Secretary of the Ministry of Agriculture for Northern Ireland, has been seconded for a period of six months to take up the post of director of agricultural production and research under the Food and Agriculture Organisation of the United Nations. Dr. Scott Robertson went to Northern Ireland in 1922 and held the dual post of professor of agricultural chemistry in the Queen's University of Belfast and senior research officer of the Ministry of Agriculture. It was during this period that he continued the now classic work on phosphatic fertilizers which he had been conducting for several years in Essex while head of the Agricultural Chemistry Department of the East Anglian Institute of Agriculture. At the same time Dr. Scott Robertson started a series of investigations on the mineral requirements of farm livestock, paying particular attention to those of poultry. This work was carried out in close collaboration with Sir John Boyd Orr, who was then director of the Rowett Research Institute. In 1928, Dr. Scott Robertson became chief inspector of the Ministry of Agriculture for Northern Ireland, and later was appointed permanent secretary when Dr. J. S. Gordon retired. For many years Dr. Robertson has acted as assessor on the Agricultural Research Council and United Kingdom delegate to the meetings of the Imperial Agricultural Bureaux. Thus he brings to his new work many years experience in agricultural research, coupled with administrative knowledge gained as head of a department the energies of which have been devoted to the task of production at the highest possible level for more than seven years.

Research in the Region between Subsonic and Supersonic Speeds

There is a large gap in our knowledge which must be bridged before we can take decisive steps from present aircraft subsonic speeds to supersonic speeds. There is first of all the question as to what happens when actually passing through the range of speed about that of sound. It is known that we must expect a steep rise of drag in this region, but we have no quantitative information. There is the further question of change of trim and stability in level flight as one passes from subsonic to supersonic speeds. There are other questions of aerodynamic and structural significance, and the whole problem is rather complex. Normally one would expect to get a large part of this information from wind tunnels, and although the capabilities of existing wind tunnels will be used to the limit, nobody knows how to design or use a practicable wind tunnel at or about the speed of sound. The phenomenon known as 'choking' and the effect of wall interference prohibit the use of tunnels for model tests at Mach numbers between about 0·9 and 1·15. This is the main reason for going into the air, and a series of experiments has been planned to use flying model aircraft launched from a great height from another aircraft and powered by rockets. This form of propulsion should enable the models to be driven through the speed-range of that of sound to various supersonic speeds.

The models will be fitted with instruments, and a six-channel telemetering system will transmit readings continuously to the ground, giving information on speed, height, Mach number, drag, lift coefficient and

longitudinal trim. Radar observations will also be made on the flight path. All this involves a new research technique, and early experiments will be mainly concerned with perfecting it. Step by step it is hoped to reach the position where enough information will be available to design a supersonic radio-controlled aircraft. The rocket thrust is about 850 lb. acting for some 70 sec. An auto-pilot controls the model in pitch and roll. It is proposed to release the model at 36,000 ft. from a Mosquito aircraft, when the controls will operate to cause it to glide down to 35,000 ft. The rocket motor will then be switched on to accelerate the model in roughly level flight, at this height, to an estimated Mach number of about 1·3. When the fuel is all burnt the model will decelerate, its speed passing through that of sound to subsonic velocity; so a double chance will occur of getting readings in the critical transonic region before the automatic controls operate to crash the model into the sea. The models have been designed by Mr. B. N. Wallis, of Vickers-Armstrong, and made there in collaboration with the Royal Aircraft Establishment, which is responsible for the conduct of these experiments. The experiments should start in about a month's time off the Scilly Isles.

Chemistry at the University of Sheffield

THE Staveley Coal and Iron Co., Ltd., near Chesterfield, has decided to make a gift of £50,000 to the University of Sheffield in order to promote the furtherance of research within the University and especially in the Department of Chemistry. The Company, which is concerned with the production of iron, caustic soda, chlorine, hydrochloric acid, chlorates, aniline and a wide range of basic coal-tar products, takes the view that encouragement of free chemical research in universities must, in the long run, benefit both the Company and industry as a whole, and believes that the connecting of industrial development with academic discovery is essential for national prosperity. Its gift to Sheffield is most opportune, as the provision of a new Department of Chemistry is one of the most urgent parts of the post-war plans of the University's extension scheme. It is intended to replace the existing laboratories, built in 1905, by an entirely new department which will be close to the present building of the University in Western Bank. The new building has been designed to provide adequate space for all the work in the Department when the University attains its projected number of 3,000 full-time students in all faculties, and adequate research facilities will be provided for investigations in analytical, inorganic, physical and organic chemistry. It is estimated that the cost of the erection of the new Department will exceed £400,000, and it is proposed that the research laboratories therein should be named the "Staveley Laboratories".

A New Rat Poison

To the well-known list of rat poisons, such as arsenic trioxide, red squill and zinc phosphide, the last years of the War added another, α-naphthathiourea. Dr. C. P. Richter, of Baltimore, was responsible for showing that its toxicity to *Rattus norvegicus* was high (A.L.D./50, 10 mgm. per kilo body-weight). Somewhat extravagant claims were made for its effectiveness when applied as a direct bait. In none of the field tests were accurate censuses made of the rat population before treatment. Prolonged and detailed experience in Great Britain at the Bureau of Animal Population has shown that knowledge obtained by bait census is essential before field trials are undertaken. The use of α-naphthathiourea as a dusting powder, however, opened up possibilities of a new method of application, but its usefulness depended upon the safety factor involved. Toxicity tests made on other animals showed an enormous range of sensitivity. *R. rattus*, the ship or black rat, had an A.L.D./50 of 250+ mgm. per kilo body-weight, more than twenty-five times that for *R. norvegicus*, while *Mus musculus*, the house mouse, had an A.L.D./50 of 80–90 mgm. per kilo body-weight. These data showed that it was impossible to predict a safety-level from one species to another. Consequently, although tests on monkeys (*Macacus* sp.) showed a high resistance, it was dangerous to assume that man was equally immune. Dusting application was therefore not advised in Great Britain until more information was available.

Used in baits, following the pre-baiting technique worked out by the Bureau of Animal Population, α-naphthathiourea gave results as good as those with arsenic and zinc phosphide, namely, 90 per cent kills; used as a direct bait without prebaiting, some successes were met with, but also the usual failures (for example, 40 per cent kill). Since the failure to exterminate rats is largely due to the hit and miss nature of direct baiting which has been employed for so long, there seemed no grounds for regarding α-naphthathiourea as any considerable advance on the well-established poisons. α-Naphthathiourea is now being marketed by the Rodmill Chemical Co., Ltd., as 'Antu', containing 2 per cent of the active principle. As a ready-to-use compound bait, 'Antu' must be classed with the direct baits which do not allow the purchasing public to pre-bait and ensure success. It is also being recommended as a dusting powder for use in rat runs, on beams and elsewhere "inaccessible to domestic animals"—places which may be hard to find. From the point of view of rodent control, it is to be regretted that α-naphthathiourea is not being marketed at a 20 per cent concentration in an inert medium and so allowing the public to obey the recommendations of the Infestation Division of the Ministry of Food to pre-bait before poisoning, a technique worked out by the Bureau of Animal Population during the War, which has proved itself again and again to be the only really certain way of exterminating rats.

Exhibition of Applied Photography

AN Exhibition of Applied Photography arranged by Kodak Ltd. at Australia House, Strand, London, was opened on May 6 by Prof. E. N. da C. Andrade. The exhibits illustrate a very wide range of industrial and commercial applications of photography, the applications being illustrated by photographs, diagrams and in some cases demonstrations. Photography received a fair amount of publicity during the War, particularly on account of its obvious importance for air reconnaissance. There were, however, many other applications less spectacular, but nevertheless of great value, many of which are illustrated in some form in this exhibition. Most of these applications have come to stay and will play a useful part in peace-time industry. The range covered by the exhibition is very wide; on the spectacular side is a full-sized radiograph of a 'Jeep' to set against the purely utilitarian micro-copying of documents. Other exhibits include industrial radiography, gamma radiography, stereoscopy, photography in education, colour reproduction and the reproduction of drawings

on metal. Among the most interesting exhibits are the 16-mm. projectors showing continuously running films of mechanical and manual operations, some in slow motion, to illustrate how an analysis of the motion can be used to speed up, or reduce fatigue in, the operation. Most of the exhibits illustrate industrial applications of photography, and the whole provides an interesting collection well worth a visit. The exhibition remains open until May 16.

Congresses

Radiation Chemistry and Photochemistry

A SYMPOSIUM on radiation chemistry and photochemistry is being arranged at the University of Notre Dame during June 24–27. Particulars can be obtained from Prof. Milton Burton, Department of Chemistry, University of Notre Dame, Notre Dame, Indiana.

Spectroscopy

THE Groupement pour l'Avancement des Méthodes Spectrographiques is organising a general meeting to be held during June 23–25 at the Laboratoire Central de l'Armement, 1 place Saint-Thomas d'Aquin. Two sessions will be devoted to emission spectroscopy and the third more particularly to colorimetric methods of analysis. Particulars can be obtained from the offices of the Group at the place of meeting.

Aeronautics

AN Aeronautical Congress will be held in London during September 3–6, at which papers will be read, followed by discussions, on the technical aspects of aviation. The Congress is being arranged by the Royal Aeronautical Society in close co-operation with the Institute of the Aeronautical Sciences of America, and about half the papers will be by American authors. A tentative programme of some twenty papers has been arranged under the following sections: aerodynamics, structures, power plants, stability and control, air-worthiness and safety, high-altitude flight, telemetering, helicopters and light (personal) aircraft. A detailed programme will be available shortly from the Royal Aeronautical Society.

Physical Chemistry

AN advanced course in physical chemistry for graduates in industry, colleges of technology and schools, will be held at the University of Leeds during August 25–September 5. The main topics will be the wave nature of matter in chemistry; molecular structure and chemical reactions; the arrangement and structure of molecules in the solid state. Particulars of the course and forms of application may be obtained from the Director of Extra-Mural Studies, The University, Leeds 2.

Cytology

THE sixth international Congress of Experimental Cytology will meet in Stockholm during July 10–17. The Congress will consist of a series of symposia on (*a*) chemical constituents of the cell; (*b*) submicroscopic structure of protoplasm (including viruses); (*c*) nuclear and cytoplasmic interactions; (*d*) cell metabolism; (*e*) development, growth and differentiation. General surveys will be given, followed by discussions and short papers relating to the above subjects. The organising committee is prepared to arrange accommodation. Particulars relating to the Congress can be obtained from the secretaries, Prof. T. Caspersson and H. Hydén, Karolinska Institutet, Institute for Cell Research, Stockholm.

Announcements

A MEETING in memory of Paul Langevin has been arranged by the Society for Visiting Scientists, the Association of Scientific Workers and the World Federation of Scientific Workers, to be held on May 25 at 7.45 p.m. at the Beaver Hall, Garlick Hill, London, E.C.4. Sir Henry Tizard will take the chair, and the speakers will include M. Pierre Biquard, of the French Commissariat of Atomic Energy and the Paris School of Physics and Chemistry, Sir Harold Spencer Jones, Sir George Thomson and Prof. J. D. Bernal.

DR. LAWRENCE L. LACHAT, senior fellow at the Mellon Institute, Pittsburgh, Pa., has resigned to accept a new position with the Chemical Research and Development Department, Armour and Co., Chicago, Ill., where he will be in charge of the development of new biochemicals which largely became available as a result of war-time research between Armour and Co. and the U.S. Office of Scientific Research and Development.

RECENT publications of the Federal Security Agency, U.S. Office of Education (Washington: Gov. Printing Office), are of interest as showing the heed paid by the United States as to the state of education in South America. Three bulletins at hand deal with Costa Rica, Colombia and Peru, and all of them merit attention by students of comparative education.

A FULL report of the two-day conference on "Industry and Research" arranged by the Federation of British Industries in March, 1946 (see *Nature*, **157**, 684; 1946), has now been published by Sir Isaac Pitman and Sons, Ltd. (London, 1946. 10*s.* 6*d.* net). It includes a preface by Sir Clive Baillieu, and, in addition to the papers presented, the addresses of the various chairmen and reports of the discussions at the sessions on scientific research and production, scientific research and industrial expansion and the application of research in industry.

WITH the financial help of private individuals and of the Juan Bautista Sauberan Foundation of Buenos Aires, an institute for research in fundamental branches of medicine has been organised in Córdoba, Argentina (25 de Mayo 1122); it will be known as the Instituto de Investigación Médica para Promoción de la Medicina Científica. The staff includes, among others, Dr. Oscar Orias (director), Dr. Enrique Moisset de Espanés and Dr. Inés L. C. de Allende. All three formerly held travelling fellowships of the Rockefeller Foundation; Dr. Orias working at Western Reserve and Harvard Universities with Profs. Carl J. Wiggers and the late Walter B. Cannon; Dr. Moisset de Espanés at Harvard University with Prof. Otto Krayer, and Dr. de Allende in Rochester, N.Y., and New York, with Profs. George W. Corner and Efrain Shorr. They held posts in the Institute of Physiology in the Medical School of the University of Córdoba, but resigned after the recent changes in the administration of the universities of Argentina. The new Institute is a private institution; its main activity will be research in endocrinology, pharmacology and physiology of the circulation of the blood.

ERRATUM. In the penultimate paragraph of "Synthesis of Methionine and Similar Amino-Acids" by J. R. Catch *et al.* (*Nature*, April 26, p. 578), for "α-amino-γ-thio-1-γ-methyl-*n*-valeric" read "α-amino-γ-thiol-γ-methyl-*n*-valeric".

LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications

A Methyl Methacrylate–Silica Replica Technique for Electron Microscopy

Barnes, Burton and Scott[1] have described a modified polystyrene–silica replica technique for the study of organic surfaces; but owing to the high temperatures (130° C.) involved in the formation of the intermediate replica, their method is unsuitable for water-containing substances. They suggest, however, that some plastics such as isobutyl-methacrylate are sufficiently thermoplastic at temperatures below 100° C. to give the necessary resolution without total drying of the specimen.

We have used a method of actual polymerization from the liquid monomer of methyl methacrylate poured over the surface of the specimen, and by it obtained electron-micrographs of silica replicas of metallic surfaces, blood cells, *Leptospira* and other materials. The intermediate replica may be formed at any convenient low temperature—even at room temperature or below—and no pressure is required since the monomer is applied as a liquid, the viscosity of which is entirely under control. Thus it is only necessary to remove any surface water from the specimen to be examined.

In the case of metallic surfaces, the method has, in general, no advantage over the polystyrene-thermoplastic technique, but may be useful in the case of metals which oxidize very readily. Its importance is obvious in the examination of biological material.

Figs. 1, 2 and 3 are examples of the electron micrographs, methyl methacrylate being used for the intermediate replica in each case. Fig. 1 was obtained from *Leptospira canicola* dispersed on a glass slide, fixed in osmic acid vapour and superficially dried; Fig. 2 shows twinning and grain boundaries in thermally etched silver, and Fig. 3 shows fine structure in pearlite steel. For comparison with Fig. 1, Fig. 4 is an electron-micrograph of *Leptospira canicola* obtained with the organism mounted on a nitrocellulose film in the electron microscope. The close similarity between Figs. 1 and 4 suggests that *Leptospira* is not changed by the electron bombardment and drying which it undergoes in the electron microscope.

To obtain the methyl methacrylate replica, methyl methacrylate monomer stabilized with 0·1 per cent hydroquinone is treated in the following way (the stabilized monomer may be obtained from I.C.I. Ltd. under the trade name of 'Kallodoc'). The method is very similar to that used by workers in other fields.

Step 1. The hydroquinone is removed in caustic soda by shaking 100 c.c. of the stabilized material with 20 c.c. of 20 per cent (w/v) aqueous caustic soda in a separating funnel and running off the brown bottom layer. The methyl methacrylate is washed with two lots of distilled water in a separating funnel, the bottom layer being run off in each case, and it is dried by standing for a night over about 5 gm. of anhydrous calcium chloride in a beaker. This destabilized liquid may be kept in a cool dark place for some months.

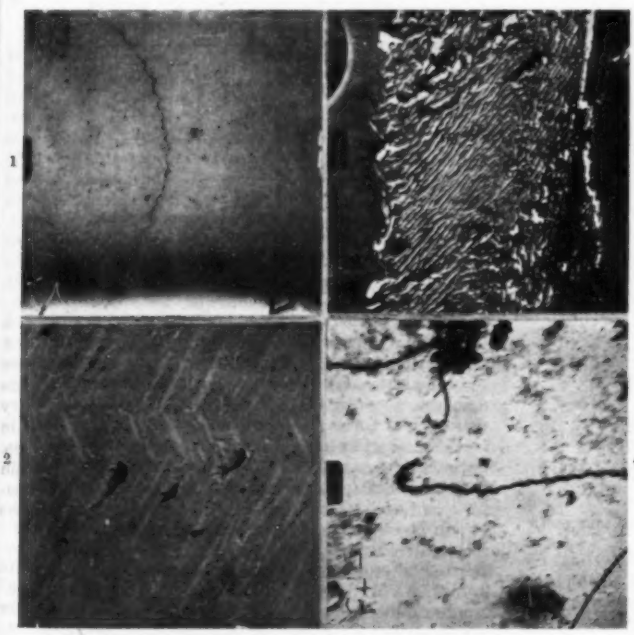
Step 2. About 5 c.c. of the destabilized methyl methacrylate is heated at 90° C. for about half an hour with 0·003 gm. of benzoyl peroxide. The time of heating may be varied to give a more or less viscous liquid. A lower viscosity will give a better resolution through being able to enter the small interstices of the surface, but will take considerably longer to polymerize on the specimen.

Step 3. (*a*) The treated methyl methacrylate from (2) is poured over the specimen and allowed to 'set' at 60° C. overnight; or (*b*) the treated methyl methacrylate from (2) is allowed to cool to room temperature (or below if required) and is then poured over the specimen and allowed to 'set' at this temperature.

The methyl methacrylate is now teased from the specimen with a razor blade and is coated with silica as described by Heidenreich and Peck[2] in the polystyrene–silica replica technique. The method of removing the silica is also analogous to that used in the polystyrene–silica method, the only difference being that the methacrylate is dissolved away in toluene and the silica films washed in clean toluene.

Methyl methacrylate has an advantage for this replica technique in that pieces of the body investigated, which might stick in the methacrylate, may be removed in dilute acids or dilute alkali without impairing the replica. *Leptospira*, for example, dissolves in 5 per cent (w/v) nitric acid.

A silica replica is also preferred to a 'Formvar' or collodion replica, this being also found by other workers[3].



Magnifications: Figs. 1, 3 and 4, × 5,000; Fig. 2, × 2,000

Dr. J. A. H. Wylie of the Sir William Dunn School of Pathology, Oxford, prepared and dispersed the *Leptospira*, and Miss D. M. Williams assisted with all the electron-microscopy work. The work was started at the Clarendon Laboratory, Oxford, and continued at the Atomic Energy Research Establishment, and was done with an R.C.A. *EMC* console type electron microscope. It is published by permission of the Director, A.E.R.E.

A. F. Brown

Cavendish Laboratory, Cambridge.

W. M. Jones

X-Ray Group, A.E.R.E., Harwell.

Feb. 14.

[1] Barnes, R. B., Burton, C. J., and Scott, R. C., *J. Appl. Phys.*, **16**, 730 (1945).
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Optimum Disturbing Field for Synchrotron Beam Ejection

Several methods have been suggested[1,2,3] for using disturbing magnetic fields to eject an electron beam from a synchrotron or betatron. Important differences exist in these methods in the angular distribution of these disturbing fields. Thus the 'orbit expansion' method[1,2] effectively applies a sudden decrease of field over the whole 360° of annulus, while the '+ − field' method[3] decreases the field over 180° of annulus, while increasing it over the other 180°. The considerations outlined in this communication lead to the suggestion of an 'optimum step field', that is, a disturbing field of angular length such that the required beam displacement is obtained with minimum reactive power in the ejector field coil.

Consider the motion of an electron of energy $E = 300\,H_0r_0$ in the magnetic field:

$$\left.\begin{aligned} H &= (H_0 - \Delta H_0)\,(r/r_0)^{-n} \text{ for } -\theta_1/2 \leqslant \theta \leqslant \theta_1/2 \\ H &= H_0\,(r/r_0)^{-n} \text{ elsewhere.} \end{aligned}\right\} \quad (1)$$

The decrease in field, ΔH_0, causes an increase in equilibrium orbit radius of Δr_0, where, letting $K = \sqrt{1-n}$,

$$K^2\,\Delta r_0/r_0 = \Delta H_0/H_0. \quad (2)$$

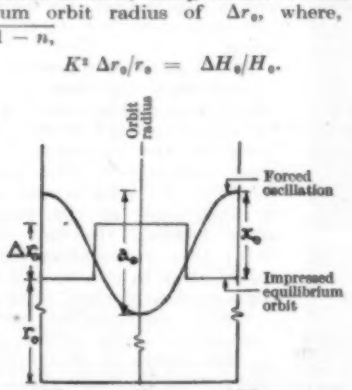

Fig. 1. Typical forced oscillation in optimum step field

Provided ΔH_0 is introduced so slowly that free oscillations are not excited, the motion of the electron is a forced one, repeating itself each revolution. Its maximum radial displacement x_0 from r_0 is given by

$$x_0 = \Delta r_0 \sin \tfrac{1}{2}K\theta_1/\sin K\pi; \quad (3)$$

and the overall amplitude of the forced oscillation by

$$a_0/x_0 = (\sin K\pi)\,(\tan K\pi/2 - \tan K\theta_1/4). \quad (4)$$

Now the reactive power required to build up the disturbing field, ΔH_0, in a fixed time is proportional to $\theta_1(\Delta H_0)^2$ and, therefore, using (2) and (3) we have, for the power required to produce a given x_0,

$$P = \tfrac{1}{4}P_1\,(\sin^2 K\pi)\,(\theta_1/\sin^2 \tfrac{1}{2}K\theta_1), \quad (5)$$

where P_1 is a constant. P is minimum when

$$K\theta_1 = 133°\,34', \quad (6)$$

which gives for the minimum power:

$$P = 1{\cdot}37\,P_1\,(\sin^2 K\pi)/K. \quad (7)$$

It will be seen that (6) defines an angle $\theta_1 < 360°$ provided $0{\cdot}37 \leqslant K \leqslant 1$. If $0 \leqslant K < 0{\cdot}37$, however, 360° must be taken as the optimum attainable value for θ_1, and (7) is replaced by

$$P = \pi P_1. \quad (8)$$

To assess the value of the above considerations, the power required to produce the same x_0 has been calculated for two other ejection methods. For the 'orbit-expansion' method we have, clearly, as in (8)

$$P' = \pi P_1 \ldots 0 \leqslant K \leqslant 1; \quad (9)$$

while, for the '+ − field' method, the equivalent of equation 3 is $x_0 = \Delta r_0\,(\sec \frac{1}{4}K\pi - 1)$, which leads to

$$P'' = (4\pi/(\sec \tfrac{1}{4}K\pi - 1)^2)P_1 \ldots 0 \leqslant K \leqslant 1. \quad (10)$$

These powers are compared in Fig. 2, from which the advantage of an optimum step-field is clear.

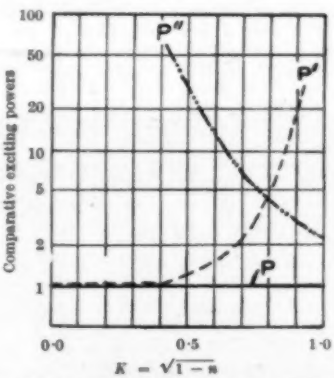

Fig. 2. Comparative powers for given displacement

In most cases, reactive power considerations will be the only important ones and the optimum step field will be used. However, in the particular case of using an external injection gun and extractor (say, a magnetic shunt[1]), both in the plane of the electron orbits, the forced oscillations are used to clear the injector during extraction. It will be seen from equations 4 and 6 that the overall amplitude of the forced oscillations, a_0, is $\geqslant x_0$ provided $1 \geqslant K \geqslant 0{\cdot}68$. In this range, therefore, the optimum step field gives the same clearance as the '+ − field', for in the latter case, although a_0 is always equal to $2x_0$, the undisturbed equilibrium orbit only clears the extractor by x_0. For $0 \leqslant K < 0{\cdot}68$ the clearance with the optimum field method is less than with the '+ − field' method, for example, at $K = 0{\cdot}55$ it is $0{\cdot}5x_0$. In general, however, sufficient clearance can be obtained,

still maintaining high power efficiency, by using a step field of less than optimum length.

This work was carried out by the Atomic Energy Research Establishment Group at the Telecommunications Research Establishment, Malvern, and acknowledgment is made to Dr. J. D. Cockcroft for permission to publish these results.

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Feb. 24.

[1] Skaggs, Almy, Kerst and Lanzl, *Phys. Rev.*, **70**, 95 (1946). Kerst, *Rev. Sci. Instr.*, **13**, 387 (1942).
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Structure of Graphite

THE recent communication in *Nature*[1] by J. Gibson directing attention to new extra lines in the X-ray powder diffraction pattern of graphite led us to re-examine a number of photographs of purified natural and artificial graphites taken some time ago. There appeared to be no extra lines in the positions observed by Gibson, although there were some exceedingly faint ones in other positions.

It seemed to us important to attempt to test the validity of Gibson's findings, because, if his extra lines were genuine, certain important modifications of the structure of graphite would be necessary. Our conception of the variations which may possibly occur in the graphite structure would permit the observation of weak extra lines at angles higher than that of the $10\bar{1}0$ reflexion from hexagonal graphite but would preclude any others, unless periodic inclusions are present. Now Gibson's strongest extra lines are precisely these 'forbidden' low-angle (high-spacing) deflexions.

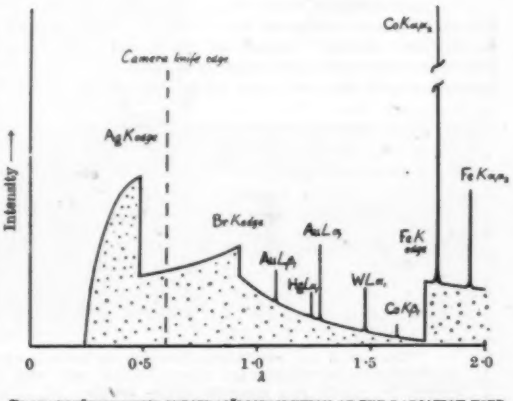
If these structural variations are not present in appreciable proportions, the origin of the extra lines must be connected with the presence of impurities either in the specimen or in the spectrum of the X-radiation used in producing the pattern. To test the first possibility, Dr. Gibson very kindly sent us some of his purified (but not heat-treated) Ceylon graphite; its ash content was stated to be 0·07 per cent. A photograph was taken of this specimen, supported in a flat, 0·03-mm. thick, 'Cellophane' holder in an 11·5-cm. diameter Seeman–Bohlin focusing camera using cobalt $K\alpha$ radiation reflected from a bent quartz monochromator. No extra lines were seen other than weak rhombohedral lines. We also took ordinary Debye–Scherrer powder photographs in a 9-cm. camera using copper $K\alpha$ radiation reflected from a plane pentaerythritol crystal, and again observed no 'extra' lines other than those corresponding to the rhombohedral structure.

This suggested that the filtered radiation used by Gibson probably contained substantial amounts of wave-lengths other than cobalt $K\alpha$, and a more detailed examination of the θ values given by Gibson in his note confirmed this supposition. When the wave-lengths of the first six lines were calculated from the Bragg relationship assuming reflexion from the 0002 planes, it was seen that they agreed well with wave-lengths of various metals; reflexion of these same radiations from other graphite planes accounted for the remaining ten lines.

Measurements taken from Gibson's table		Impurity† wave-length		Corresponding‡ wave-length	
Line No.	$\theta°$	λ (in kX.)	Reflected from	λ (in kX.)	Element series
• 1	9·38	1·091	0002	1·081	Au$L\beta_1$
• 2	10·66	1·238	0002	1·239	Hg$L\alpha_1$
• 3	10·98	1·275	0002	1·274	Au$L\alpha_1$
• 4	12·68	1·469	0002	1·473	W$L\alpha_1$
• 5	13·96	1·615	0002	1·617	Co$K\beta_1$
• 6	16·79	1·934	0002	1·934	Fe$K\alpha_1\alpha_2$
7	17·81	1·240	$10\bar{1}1$	1·239	Hg$L\alpha_1$
8	18·40	1·279	$10\bar{1}1$	1·274	Au$L\alpha_1$
9	21·32	1·474	$10\bar{1}1$	1·473	W$L\alpha_1$
•10	22·44	1·278	0004	1·274	Au$L\alpha_1$
11	28·41	1·929	$10\bar{1}1$	1·934	Fe$K\alpha_1\alpha_2$
12	31·39	1·279	$11\bar{2}0$	1·274	Au$L\alpha_1$
13	33·71	1·282	$11\bar{2}2$	1·274	Au$L\alpha_1$
14	36·82	1·472	$11\bar{2}0$	1·473	W$L\alpha_1$
15	39·72	1·476	$11\bar{2}2$	1·473	W$L\alpha_1$
16	67·30	1·472	$21\bar{3}1$	1·473	W$L\alpha_1$

• Doublet.
† Calculated from the values of the cell dimensions of graphite obtained by Nelson and Riley[4].
‡ Taken from Siegbahn's "Spectroscopy of X-rays" (Oxford University Press, 1925).

It appears clear from the table that Gibson's extra lines can be attributed to the presence of small amounts of iron, gold, mercury and tungsten in the cobalt target plating. The fact that only the lines arising from the basal plane reflexions are doubled lends support to this conclusion, as these reflexions only are usually doubled in ordinary powder photographs of graphite[2]. It will be noticed that a number of lines which should be present have apparently not been observed by Gibson. In most cases this is due to their coincidence or close proximity with either strong cobalt $K\alpha$ lines (Au$L\alpha_1$ from $21\bar{3}1$, W$L\alpha_1$ from 0004, Fe$K\alpha$ from 0004, $11\bar{2}2$ and $11\bar{2}0$, Hg$L\alpha_1$ from $11\bar{2}0$ and $21\bar{3}1$) or with the impurity radiation lines themselves (Hg$L\alpha_1$ from 0004 and $11\bar{2}2$). The iron filter used to reduce the intensity of the cobalt $K\beta$ does not appear to have been chosen of optimum thickness. Moreover, the use of an aluminium screen in front of the photographic film is a practice which accentuates the effects of harder radiation[3] and does not in general reduce 'back-ground scatter'. The effect on the photographic films of the wave-length/intensity distribution of the radiation used is probably something like that shown in the accompanying figure.



PROBABLE EFFECTIVE SPECTRAL DISTRIBUTION OF THE RADIATION USED

For most X-ray diffraction work, carefully filtered radiation is perfectly adequate. However, it is clear from this work that for the detection of second-order effects, slight amounts of extra phases, or for the examination of disordered or amorphous substances, the use of crystal-reflected radiation is essential, if the introduction of spurious detail into the diffraction pattern is to be avoided.

It is interesting to observe here that with the ordinary 19-cm. diameter powder camera, together with a specimen rod of a pure substance giving well-spaced strong reflexions, it is a comparatively simple matter to test the purity of the filtered X-ray beam.

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[1] Gibson, J., *Nature*, **158**, 752 (1946).
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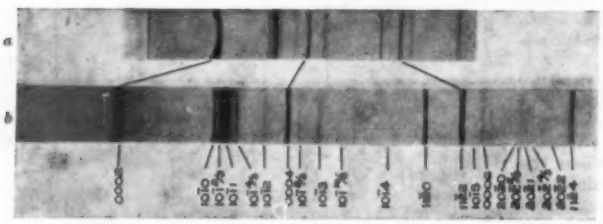
A RECENT communication by Gibson[1] sought to show that X-ray powder photographs of graphite contained 'extra' reflexions that could not be explained on the basis of the co-existence of the hexagonal and rhombohedral structures described by Lipson and Stokes[2]. It is of some importance that the crystal structure of graphite should be correctly specified[3], and, because of our experience in examining by X-ray methods graphites from many different sources, we have thought it useful to investigate the validity of the observations made by Gibson. Besides the particular problem of the structure of graphite, there are also involved some questions of X-ray technique on which comment appears called for.

We have re-examined a large collection of our powdered crystal patterns of graphite, and in no case has the series of 'extra' reflexions specified by Gibson been detected. In some instances anomalous faint reflexions are present on the photographs, but these are explained either by imperfect filtering of the X-ray beam or by the presence of impurities in the specimens.

The photographs were taken in either 10-cm. or 19-cm. diameter cameras, the radiation being copper *K*, filtered through nickel of thickness 0·02 mm. Extruded rod type specimens were used. The experimental conditions included hydrogen filling of the camera to reduce background scatter, but not an aluminium screen, as it is considered that no advantage is to be gained from the use of even a thin screen with such materials as graphite. The photographic density of the films appeared in every way comparable with that of Gibson's, with the background clear enough to provide favourable conditions for detection of weak lines, should they occur. The change from cobalt to copper radiation cannot be regarded as significant, for we see no reason to suppose that reflexions appearing with one radiation are likely to be suppressed when the other is used. Most of the patterns showed a faint 0002 line, attributable to the imperfect filtering action of the nickel absorbing screen; the identification of this line is a simple matter.

In order that we could rule out the possibility that our samples of graphite did not include every variant, Dr. Gibson kindly sent us specimens of two of the powders which he had used. One of them was the purified natural graphite with ash content 0·07 per cent; the other was an artificial graphite of ash content 0·05 per cent. We were also concerned to avoid any remaining ambiguities concerning the character of filtered X-radiation, and so these two specimens and a few of our own have been examined with copper *K*α radiation obtained with a flat crystal monochromator of the type described by Lipson, Nelson and Riley[4]. With a 10-cm. diameter camera, hydrogen-filled during the photographic exposure, all specimens have given X-ray patterns showing none of the anomalous reflexions specified by Gibson in his note. One of these patterns is reproduced in the accompanying figure.

A specimen of graphite which we have recently had occasion to examine provides some additional evidence concerning the hexagonal and rhombohedral structures. The X-ray powder photograph contains the usual lines for both structures, but the reflexions for the rhombohedral form, characterized by the sequence *ABCABC* . . ., are of appreciably greater density than has been noted previously. It is estimated that as much as 25 per cent of the rhombohedral type of graphite occurs in this specimen, as against 10–15 per cent in most other specimens. The relevant part of the powder photograph is reproduced below. The significant feature of the X-ray examination is that, although so many lines for the rhombohedral structure appear of enhanced strength, no anomalous or forbidden reflexions can be detected. The result provides strong confirmation of the validity of the interpretation of the X-ray data given by Lipson and Stokes. There seems little reason for doubting that all features of X-ray powder photographs of graphite are explained by the co-existence of hexagonal and rhombohedral forms.



PARTS OF X-RAY POWDER PHOTOGRAPHS OF NATURAL GRAPHITE
(*a*) Purified Ceylon graphite, ash content 0·07 per cent: with crystal monochromatized (copper *Kα*) radiation, 10-cm. camera. (*b*) Purified natural graphite, origin unknown: with filtered (copper *K*) radiation, 19-cm. camera.

In conclusion, we would endorse the remarks made by Nelson and Riley in the accompanying letter. Filtered *K*-radiation certainly provides an effective 'monochromatic' beam for general purposes. Our experience is that it is reasonably satisfactory for the examination of graphites, provided the target material is carefully selected and the X-ray set is kept in good condition. But the limitations have to be recognized, and when structural details of the type in question have to be investigated, the final test must reside with a crystal-monochromatized beam.

As Nelson and Riley point out, a reflexion of the intensity of the 0002 reflexion from graphite does, in fact, provide a good means of analysing the spectrum of the X-ray beam employed.

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Phase-Contrast in the Photomicrography of Metals

The method of phase-contrast[1] has been successfully applied in this Laboratory to the 'vertical' illumination metallurgical microscope.

In the course of studies on the microstructure of alloy steels, heat-treated to show "intermediate transformation products"[2], photomicrographs of the ordinary type, such as Fig. 1, have been obtained from samples etched with nitric acid in alcohol. These show areas of two materials, the martensite representative of the transformed austenite and the "intermediate transformation product"; but owing to their similar light-reflecting properties, it is not always easy to distinguish them from one another, and the most prominent features are simply the black lines indicating their mutual boundaries.

Electron micrographs of the same specimen, such as Fig. 2, produced from negative ('Formvar') replicas[3], give higher resolution, but, in addition, show greatly improved contrast between the martensite and the "intermediate transformation product". The latter has been attacked more rapidly by the nitric acid, and its surface-level is therefore below that of the martensite; but whereas the electron microscope technique is very sensitive to this change in level, the normal light microscope does not appreciate it.

These characteristic differences in level should give rise to characteristic differences in phase in light reflected from the metal, and the phase-contrast method will convert such differences in phase into observable differences in light intensity. (A complicating factor is the possibility of differences in phase change on reflexion depending on the varying nature of the areas as distinct from their varying levels.)

A 'vertical' illumination microscope with specially designed phase-contrast modifications has been set up, and Fig. 3 is a phase-contrast photomicrograph obtained from it. There is a very clear distinction between the "intermediate transformation product" (dark areas) and the martensite (light areas), and the general correspondence between the tone values in this phase-contrast photomicrograph and those in the electron micrograph of Fig. 2 is noteworthy.

Since contrast-levels can so easily be adjusted photographically by suitable choice of plates and printing papers, Fig. 4 is included as a 'control' on Fig. 3. It shows yet another area of the same specimen taken with the same objective lens (42-mm. oil immersion) and with the same photographic materials as the phase-contrast photomicrograph of Fig. 3, but *without* phase-contrast and at a somewhat reduced aperture.

Direct observation on the 'vertical' illumination phase-contrast microscope therefore provides valuable information previously only obtained indirectly through the agency of replicas and photographic means on the electron microscope. Such direct observation is a very valuable feature, and it is therefore felt that this development places in the hands of metallurgists and others interested in surface structures a new tool of considerable interest.

Further details will be published elsewhere.

Fig. 1

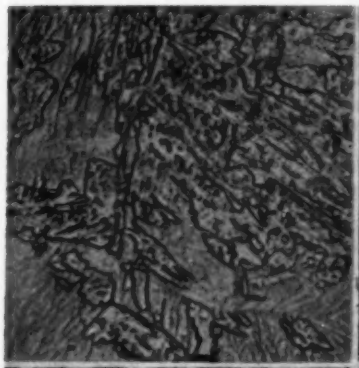
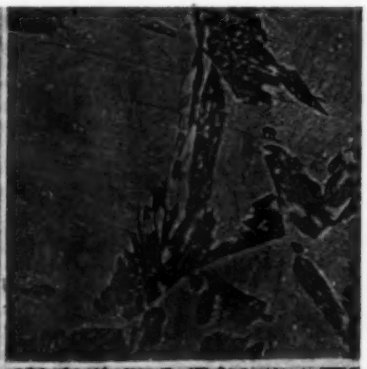
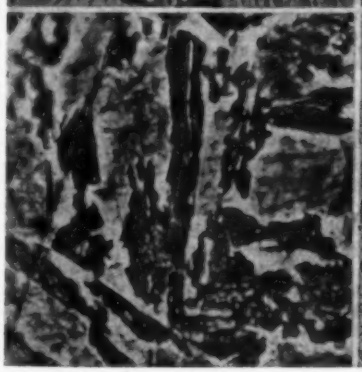


Fig. 2





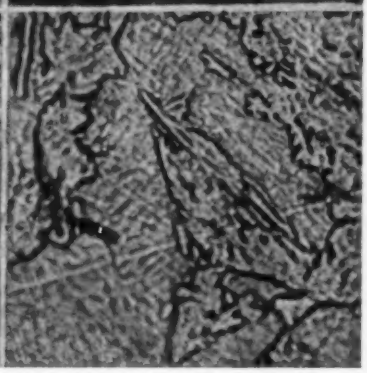


Fig. 3

Fig. 4

Fig. 1. Normal photomicrograph
Fig. 2. Electron micrograph
Fig. 3. Phase-contrast photomicrograph
Fig. 4. Photomicrograph control for Fig. 3. × 1,600

The work described here has been carried out as part of the general research programme of the National Physical Laboratory, and this note is published by permission of the Director of the Laboratory.

The photomicrograph of Fig. 1 was prepared by Mr. J. L. Heslegrave and the electron micrograph of Fig. 2 by Mr. J. Trotter.

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Felting of Animal Fibres

WHEN a mass of loose wool or fur is rubbed in presence of an aqueous solution of acid or alkali, a felt is produced because the surface scale structure of the fibres causes them to migrate in the direction of their root ends. In the preparation of rabbit fur for felting, it is customary to treat the tip ends of the fibres, before the skin is cut away, with a solution of mercuric nitrate in nitric acid. The process, known as 'carroting', has the effect of enhancing the felting power of the fibres, and similar results can be obtained with other oxidizing agents, such as hydrogen peroxide, in presence of suitable catalysts. In all cases, the essential reaction is disulphide-bond breakdown, which was believed to be beneficial[1] because the tip ends of rabbit fibres are coarser than the roots. After treatment, the tips of the fibres are much less resistant to deformation, with the result that they are able to follow the finer root ends through entanglements which would otherwise have obstructed further movement and felting.

Although the process of 'carroting' is centuries old, its exact purpose has only recently been recognized[1], and no attempt has been made, therefore, to enhance the felting power of fur fibres by using reducing agents, instead of oxidizing agents, to cause disulphide-bond breakdown in the tips. It has now been found that treatment with a 10 per cent solution of sodium metabisulphite in aqueous alcohol[2] for one hour at 50° C. is particularly effective, even with wool fibres, which are uniform in diameter along their length.

Locks of 58's Australian cross-bred wool were treated with sodium metabisulphite over various fractions of their lengths, starting from the tip, 'carded', and then felted (4-gm. samples) for 30 minutes in presence of soap in a model felting machine[3]. The results are given in Table 1, where the degree of felting is indicated by the value of the 'compression resistance', which is the ratio of the thicknesses of the felted pad under standard high and low pressures. Maximum felting is obtained when half the length of the fibres, starting from the tip, is treated with sodium metabisulphite.

TABLE 1

Reagent	Fraction of lock treated	Compression resistance
Sodium metabisulphite	None	0·717
	Tip ¼	0·814
	Tip ½	0·826
	Tip ¾	0·720
	Whole lock	0·609

It is obvious that such a high degree of entanglement as exists in a finished felt could not be brought about unless the root ends of migrating fibres are sufficiently rigid to force a way through entanglements made in earlier stages of the felting process[4]. This is, no doubt, the reason why the degree of felting is least when the whole fibre is treated with sodium metabisulphite. As, however, the flexural rigidity of intact wool fibres is low, it seemed likely that improved felting might be obtained by hardening the root ends of fibres instead of softening the tips. This deduction was confirmed by treating locks of wool with a solution of mercuric acetate (0·1*M*) in acetic acid (0·1*N*) for one hour at 25° C. Mercuric acetate is by far the most effective cross-linking agent for animal fibres[5], and the results obtained with wools which were cross-linked over various fractions of their lengths, starting from the root end, are given in Table 2.

TABLE 2

Reagent	Fraction of lock treated	Compression resistance
Mercuric acetate	None	0·717
	Root ¼	0·761
	Root ½	0·694
	Root ¾	0·545
	Whole lock	0·387

The highest degree of felting is obtained when about a quarter of the length of the fibres, starting from the root end, is treated with mercuric acetate.

As would be expected, there is a dramatic rise in the felting power of animal fibres when hardening of the root ends is combined with softening of the tips, and this principle is likely to form the basis of the 'carroting' processes of the future. At present, the best practical means of carrying out such processes seems to be to harden the whole fibre with cross-linking agents and then to soften the tip by means of reagents which cause disulphide-bond breakdown.

We are indebted to the International Wool Secretariat for grants in aid of the investigation.

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March 8.

[1] Speakman, *J. Text. Inst.*, **32**, T83 (1941).
[2] Speakman, B.P. 453,700.
[3] Chamberlain and Menkart, *J. Soc. Dyers and Col.*, **61**, 286 (1945).
[4] Martin, *J. Soc. Dyers and Col.*, **60**, 325 (1944).
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Total Emission Noise in Diodes

C. N. SMYTH[1] has shown that the space-charge between anode and cathode in the cut-off region of a diode gives rise to a large input conductance $1/R$ at ultra-high frequencies. He has also put forward arguments that the space-charge behaves as an additional source of noise at ultra-high frequencies. Hence it might be worth while to measure the 'equivalent noise temperature' T_e of the conductance $1/R$, T_e being defined by

$$\overline{i^2} = \frac{4k\,T_e\,\Delta\nu}{R}, \qquad (1)$$

in which $\overline{i^2}$ denotes the mean square noise current in a frequency interval $\Delta\nu$ and k is Boltzmann's constant.

Measurements were carried out at 7·25 m. wavelength on a diode having an emitting cathode area of about 10 cm.² and an anode-cathode distance of 0·1 cm., using a saturated diode as a standard noise generator. In this way we were able to measure the input damping $1/R$ as well as the equivalent saturated diode current I_e, defined by the relation :

$$\overline{i^2} = \frac{4k\,T_e\,\Delta\nu}{R} = 2e\,I_e\,\Delta\nu, \qquad (2)$$

where e is electronic charge.

The results are shown in Figs. 1 and 2. In Fig. 1 $1/R$ is plotted against V_a, in Fig. 2 I_e against V_a for a heater voltage $V_f = 12$ V., as well as for $V_f = 8$ V. It is shown in Fig. 2 that the equivalent noise current I_e is much larger than the anode current I_a.

Measurements of the characteristic showed that the saturation currents for $V_f = 12$ V. and for $V_f = 8$ V. differed by a factor 50. $1/R$ and I_e are only slightly dependent upon the saturation current I_s; a change in I_s by a factor 50 corresponds to a change in $1/R$ and I_e by about a factor 3.

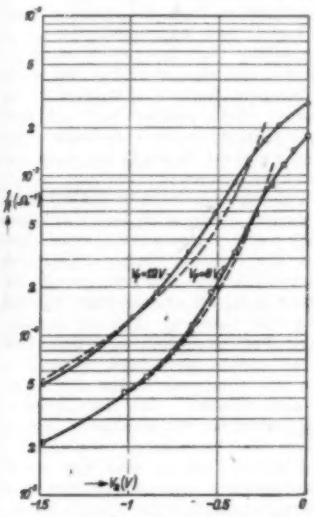

Fig. 1

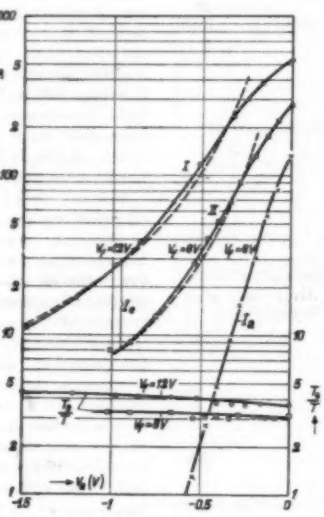

Fig. 2

Fig. 1. $1/R$ AS A FUNCTION OF V_a FOR HEATER VOLTAGES OF 12 V. AND 8 V.
Fig. 2. I_e, I_a AND T_e/T AS A FUNCTION OF V_a FOR HEATER VOLTAGES OF 12 V. AND 8 V.

$1/R$ and I_e are approximately proportional to V_a^{-2}. This follows directly from Figs. 1 and 2, in which dotted curves $C\,V_a^{-2}$ are drawn; the values of the constant C are chosen such that each dotted curve coincides with the corresponding full-drawn curve at $V_a = -1{\cdot}0$ V. As T_e is proportional to $I_e R$, we should expect T_e to be approximately independent of V_a. This is shown in Fig. 2, in which T_e/T (T denoting normal room temperature = 290° K.) is plotted against V_a for $V_f = 12$ V. and for $V_f = 8$ V. According to these curves, the average values of T_e at $V_f = 12$ V. and at $V_f = 8$ V. are approximately equal to 1,200° K. and 900° K. respectively; this nearly coincides with the actual cathode temperature.

Hence our final result is that the total emission noise may be described by assuming the 'equivalent noise temperature' T_e of the conductance $1/R$ to be equal to cathode temperature. It is to be expected from a theoretical point of view that this result will hold for a very wide frequency range, because $1/R$ and I_e are both proportional to the square of the frequency.

A fuller account of our investigations will be published elsewhere.

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[1] Smyth, C. N., *Nature*, **157**, 841 (1946).

Polarization of Infra-Red Radiation

A METHOD of making thin selenium films with free surfaces has been devised, and this has enabled us to construct a pile of selenium films which polarize a beam of radiation falling on the plates at the appropriate angle. The transmitted beam is the one which is used, and a high degree of polarization (with very little loss of efficiency) is obtained with only three films. The films are not perfectly flat; since, however, they are only a few microns thick, this introduces no distortion in the transmitted beam, and is of service in eliminating the loss of polarization due to multiple reflexions. The films show a small absorption at a wave-length of 2 μ, but are otherwise transparent so far as we have examined them (about 7 μ).

Some interesting cases of pleochroism in sucrose have been reported by Ellis and Bath[1], who observed the absorption of radiation polarized by a Glan–Thompson calcite prism in the very near infra-red (up to 1·7 μ). This method restricts observation to the overtones of the molecular vibration bands which occur in this region. The selenium polarizer, however, can be used over a wide range of wave-lengths in the infra-red spectrum. We have made preliminary experiments to determine how the intensity of absorption depends on the orientation of the molecule with respect to the plane of vibration of the incident radiation. Marked effects have been found in the absorption spectrum of naphthalene (a crystalline material) and of nylon (an oriented film of a linear polymer). For example, in naphthalene, with the direction of propagation of the incident radiation perpendicular to the plane containing the a and b axes, and the electric vector parallel to the b axis, the absorption of bands at 3·3 μ, 2·1 μ, and 2·2 μ is considerably stronger than when the electric vector is parallel to the a axis. Other bands in this region are not affected. In the case of nylon, the absorptions between 3 μ and 3·2 μ corresponding to stretching the CH and NH bonds are more intense when the incident light vector is perpendicular to the direction of the stretched chains. This is in harmony with current ideas on the structure of nylon. We have also observed differences in the relative intensities of bands in the region 6 μ to 7 μ.

It is expected that the use of polarized infra-red radiation will be of service in identifying absorption frequencies with particular modes of vibration of the molecule, and in correlating the direction of valence links with the external surfaces of oriented materials.

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[1] Ellis, J. W., and Bath, Jean, *J. Chem. Phys.*, **6**, 221 (1938).

A Spherically Symmetrical Non-Static Electromagnetic Field

We have recently found the most general non-static solution of spherical symmetry satisfying the relativistic equations of electromagnetism, namely,

$$G_{\mu\nu} - \tfrac{1}{2}GJ_{\mu\nu} = -8\pi T_{\mu\nu}, \quad . \quad . \quad (1)$$

where
$$T_{\mu}^{\nu} = -F^{\nu\sigma}F_{\mu\sigma} + \tfrac{1}{4}\delta_{\mu}^{\nu}F^{\alpha\beta}F_{\alpha\beta}, \quad (2)$$

$$F_{\mu\nu} = k_{\mu,\nu} - k_{\nu,\mu}, \quad (3)$$

$$F^{\mu\nu}{}_{,\nu} = J^{\mu}, \quad (4)$$

in the usual notation[1]. The line element is

$$ds^2 = -(1 - 2m/r)^{-1}\,dr^2 - r^2(d\theta^2 + \sin^2\theta\,d\varphi^2) + \dot{m}^2(1 - 2m/r)/f^2.dt^2, \quad (5)$$

where

$$f \equiv f(m) = m'(1 - 2m/r), \dot{m} \equiv \partial m/\partial t, m' \equiv \partial m/\partial r. \quad (6)$$

The surviving components of the tensor T_{μ}^{ν} are four:

$$-T_1{}^1 = T_4{}^4 = m'^2/4\pi r^2, \; T_1{}^4 = m'\dot{m}/4\pi r^2, \quad T_4{}^1 = -\dot{m}/4\pi r^2. \quad (7)$$

If we interpret T_{μ}^{ν} as

$$T_{\mu}^{\nu} = \rho v_{\mu}v^{\nu}, \; v^{\mu}{}_{,\nu}v^{\nu} = 0, \quad (8)$$

and define

$$\frac{d}{d\tau} \equiv v^1\frac{\partial}{\partial r} + v^4\frac{\partial}{\partial t}, \quad (9)$$

$$v^1 = \sqrt{f(m)/4\pi\rho r^2}, v^2 = 0, v^3 = 0, v^4 = -m'v^1/\dot{m}, \quad (10)$$

$$dm/d\tau = 0, dv^1/d\tau = 0, d(4\pi r^2\rho)/d\tau = 0. \quad (11)$$

Both ρ and $f(m)$ are arbitrary. We note that m is conserved along a line of flow.

It is interesting to note that there are several solutions of (3) and (4) consistent with (5). One solution is given by

$$k_1 = -\frac{m'}{\sqrt{(4\pi f)}}\cos^{-1}(\sin\theta\sin\varphi),$$
$$k_2 = 0, \quad k_3 = 0, \quad (12)$$
$$k_4 = -\frac{\dot{m}}{\sqrt{(4\pi f)}}\cos^{-1}(\sin\theta\sin\varphi).$$

$F_{\mu\nu}$ and J^{μ} can be readily calculated. Results corresponding to (10) and (11) follow for this interpretation of T_{μ}^{ν}. All such solutions and their details will be published elsewhere.

The line element (5) was first published by one of us[2] some years ago. A line element equivalent to (5) but not obviously so was obtained by Mineur[3] several years earlier. No attempt, however, seems to have been made to obtain the electromagnetic interpretation of the line element in terms of k_{μ} and J^{μ}.

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[1] Tolman, R. C., "Relativity, Thermodynamics and Cosmology", 250 (1934).
[2] Vaidya, P. C., *Curr. Sci.*, **12**, 183 (1943).
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Existence of New Types of Wakes Behind a Moving Body

A question which to me seems very interesting was posed by Dr. Christopherson in *Nature* of March 8, p. 345: Can an approximate (numerical) computation establish either the existence or non-existence of a mathematical solution? He was describing a recent use of relaxation methods to find new types of wake behind a moving body, and expressed himself as satisfied that these exist. But the paper which recorded these computations also recorded failure to discover behind a 'planing surface' a motion of the fluid involving waves. This failure had not been expected, and Dr. Christopherson concludes (as I think, rightly) that it should be regarded as a null result from an ideal experiment.

For my own part, though I believe in the existence of finite wakes, I should do so with less confidence if the only evidence were the solutions which Miss Vaisey obtained on the basis of finite differences; for if the down-stream junction had been one of two streams impinging at a small angle, then (as was remarked to us by Sir Geoffrey Taylor) a small 'splash' would have been directed upstream from the junction, and this might have been so small as to escape detection (its thickness might have been smaller than our mesh-length). On that account, in the paper, an argument for the existence of finite wakes was based on the 'membrane analogue' of inviscid motion. I think that a case was made; but what I should consider a more convincing argument would be some *exact* solution for a finite wake—and I am hopeful of finding one.

As regards the motion behind a planing surface, while agreeing with the view expressed by Dr. Christopherson I should, perhaps, correct his statement that what appears to be non-existent is a motion in which the depth is the same far upstream and far downstream of the plane. What we have sought without success is a motion involving waves downstream but not upstream. I do not think it would have been difficult to find a solution involving stagnation on both sides of the plane, and the same depth far away from it; but this would have little importance, for it would also entail an infinite velocity at the trailing edge. It must be emphasized that our paper dealt with an *inviscid* fluid, in which results of this kind are acceptable mathematically, with other conclusions still less in accord with experience. All our solutions, for example, would *in theory* hold with the velocities reversed.

Our paper, being concerned with computation, did not seem to be the place for physical speculation; but for my own part I suspect that friction plays an essential part in the production of waves

behind a barrier or trailing surface. Perhaps some day we shall be able to test this conjecture by computations which take account of viscosity. I should be hopeful if I were sure that the wave motions are 'stream-line', but I suspect that the time-variable enters, and I see little prospect of handling three independent variables—at least, until machines become available.

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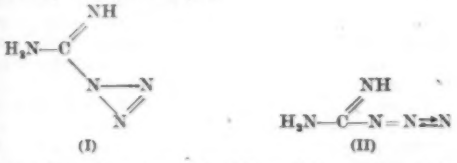
Coupling of Diazonium Complexes from an Aliphatic Base

The formation of diazonium complexes from unsaturated amines is not a unique property of the aromatic series. Many, but not all, unsaturated heterocyclic amines respond similarly[1]. With aliphatic amino-compounds, nitrous acid, under certain conditions, may give a diazo-grouping but not an ionizable diazo-derivative. In the literature it would appear that aminoguanidine is the only straight-chain compound so far recorded as being in line with the aromatic amines. Even in this example the tendency is to form an intermediate heterocyclic compound, and it is only under special conditions that a straight-chain diazonium derivative is obtained.

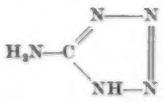
During some work on the action under different conditions of sodium nitrite on aminoguanidine, (*a*) a relationship has been found between the products formed, and (*b*) the nature of the resulting coupled-bodies also has been determined.

Thiele[2] treated aminoguanidine with sodium nitrite in the presence of free mineral acid and isolated a derivative which Hantzsch and Vagt[3] considered to be guanyl azide, with the structure shown in (I), but which in the light of modern resonance theory would probably be that in (II):



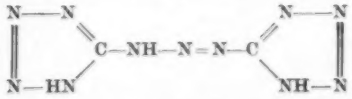
(I) (II)

This azide, when treated with weak bases, isomerized to 5-amino-tetrazole:



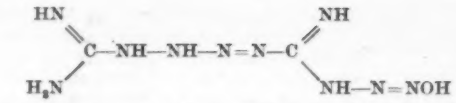
which when disazotized in the usual way gave a diazonium salt (*A*), which coupled with such intermediates as α- and β-naphthol to give azo compounds.

Hofmann and Hock[4] treated aminoguanidine with sodium nitrite in the presence of glacial acetic acid and isolated 1-3-ditetrazolyltriazene (*B*):



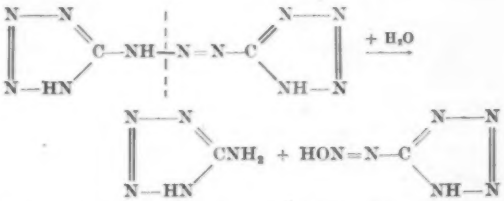
which when heated with a weakly alkaline solution of β-naphthol gave an orange-coloured solution.

The same workers[5] isolated 1-guanyl-4-nitroso-aminoguanylisotetrazene (*C*):

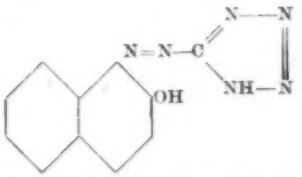


by the action of sodium nitrite on aminoguanidine in neutral solution. This also, under similar conditions, gave an orange-coloured solution with β-naphthol. This coloured compound was isolated from solution by Norris-Shreve, Carter and Willis[6], who showed that it possessed the properties of an azo dye.

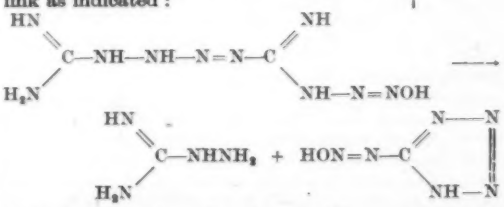
During the course of the present work, it was shown that the coloured compounds obtained with β-naphthol from each of the above three 'diazo' derivatives were identical in all respects. Their formation, however, proceeds differently. In *A*, the coupling takes place at ordinary temperatures with no evolution of nitrogen. In *B* and *C* the reaction is carried out at 80° C. In the case of *B*, splitting appears to occur at the —NH—N=N— link, forming 5-amino tetrazole and diazotetrazole (diazonium hydroxide).



This diazotetrazole now couples with the β-naphthol in the α-position forming 1-2-3-4-tetrazole 5-azo-β-naphthol.



The case of coupling with 1-guanyl-4-nitrosoamino-guanylisotetrazene (*C*) is more complicated. Splitting takes place as in the case of *B* at the —NH—N=N— link as indicated:



with the formation of aminoguanidine on one hand and diazotetrazole on the other, through ring closure as shown. The diazotetrazole couples, as in the case of *B*, if an intermediate is present. In the absence of a coupling intermediate, such as β-naphthol, the diazotetrazole loses two atoms of nitrogen, forming hydroxytetrazole.

To substantiate the structure of the foregoing β-naphthol complex, a series of reduction experiments

were carried out on this substance. In all cases the products were found to be α-amino, β-naphthol and 5-aminotetrazole.

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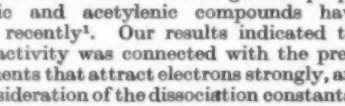
[2] Thiele, *Ann.*, **270**, 46 (1892).
[3] Hantzsch and Vagt, *Ann.*, **330**, 314 (1900).
[4] Hofmann and Hock, *Ber.*, **43**, 1866 (1910).
[5] Hofmann and Hock, *Ber.*, **43**, 682 (1910).
[6] Norris-Shreve, Carter and Willis, *Ind. Eng. Chem.*, **36**, 472 (1936).

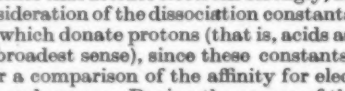
Relationships Between some Dissociation Constants

IN these Laboratories the fungistatic properties of ethylenic and acetylenic compounds have been studied recently[1]. Our results indicated that biological activity was connected with the presence of substituents that attract electrons strongly, and led us to a consideration of the dissociation constants of compounds which donate protons (that is, acids as defined in the broadest sense), since these constants form a basis for a comparison of the affinity for electrons of radicals and groups. During the course of this work, relationships were found between certain dissociation constants, which constants are conveniently expressed as ΔF ($= -RT.\log_e K$)[2] for the reaction $RH \rightarrow R^- + H^+$ taking place in dilute aqueous solution at 25° C. Although the relationships summarized below are of general application, space here does not permit them to be illustrated by long lists of examples, and so, as far as possible, only the values of ΔF (calories) for the seven acids, H_3PO_4 (I) + 2,900; $H_2PO_4^-$ (II) + 9,800; HPO_4^{--} (III) + 16,900; H_2SO_3 (IV) + 2,400[3]; HSO_3^- (V) + 9,800[3]; HSO_4^- (VI) + 2,300 and HOCl (VII) + 10,100[4,5], have been used in this discussion

(1) The values of ΔF for the two reactions



and



differ by 7 kgm. cal. Compare (I) and (II); (II) and (III); and (IV) and (V).

(2) The addition of a doubly bonded oxygen atom to the atom attached to a dissociating hydroxyl group decreases the value of ΔF by 7 kgm. cal.; for example, (V) and (VI). One of the two effects (1) and (2) in reverse should cancel out the other, and indeed (IV) and (VI) do agree within the limits of the experimental error.

(3) In the reaction $-Y-H \rightarrow -Y^- + H^+$, the combination of an additional proton with Y or the replacement of an atom directly attached to Y by another higher in atomic number by one unit decreases ΔF by 14 kgm. cal.; compare (III) and (VI). The difference, 14 kgm. cal., is so large that accurate measurement of both dissociation constants is usually difficult. However, the effect (3) can be reduced by combining it with (1) or (2), and the difficulty then disappears. The dissociation constant of a hydroxylic acid should, in fact, be unaltered if the atom attached to the hydroxyl group is moved back one place in the periodic table (ΔF changed by −14 kgm. cal.), and either: (*a*) two oxygen atoms are linked to the replacing atom by semi-polar double bonds ($+2\times7$) as in (V) and (VII); or (*b*) one oxygen atom ($+7$) is attached and an extra proton is put on this oxygen atom ($+7$) (examples are the pairs (I) and (IV) and (II) and (V)); or (*c*) two protons are added to oxygen atoms already attached to the replacing atom ($+2\times7$); (I) and (VI).

(4) In the reaction $-Y-H \rightarrow -Y^- + H^+$, the replacement of Y by an atom one higher in atomic number apparently decreases ΔF by 21 kgm. cal., at any rate when Y is carbon or nitrogen. This difference between the ΔF values is so large that it cannot be measured directly. However, ΔF for $AOH \rightarrow AO^- + H^+$ is greater than ΔF for $ANH_3^+ \rightarrow ANH_2 + H^+$. A comparison can be made with more than twenty different groupings for A, and the difference in the ΔF values is always close to 7 kgm. cal. This figure may be regarded as the net result of an increase in ΔF of 2×14 kgm. cal. due to the removal of two protons (effect 3) and a decrease of 21 kgm. cal. for the replacement of nitrogen by oxygen. This fourth effect is interesting because it suggests a means by which ΔF for carbon–hydrogen links can be estimated. For the dissociation of nitric acid, ΔF seems to be roughly −1,000 cal.[6]. From this by calculation for effects (3) and (4), ΔF for nitromethane should be +13,000 cal. The estimation of ΔF for nitromethane from that of nitramide (+9,000 cal.) leads to a figure of +16,000 cal. The experimental value of ΔF is +15,000 cal. The effect on the dissociation constants of pyridinium ions produced by substituents can now be used to throw light on problems of substitution in benzene derivatives.

This and other matters arising out of the discovery of these relationships will be discussed when a fuller account of this work is prepared for publication elsewhere.

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[1] Brian, P. W., Grove, J. F., and McGowan, J. C., *Nature*, **158**, 878 (1946).
[2] Most of the values given for ΔF have been calculated from the dissociation constants shown in Landolt-Bornstein's "Physikalisch-Chemische Tabellen", Berlin (1923) and Supplements (1927), (1931) and (1936).
[3] Tartar, H. V., and Garretson, H. H., *J. Amer. Chem. Soc.*, **63**, 808 (1941).
[4] Holst, G., *Chem. Abst.*, **35**, 2784 (1941).
[5] Hagiawa, H., *Chem. Abst.*, **35**, 20 (1941).
[6] Redlich, O., *Z. phys. Chem.*, A, **182**, 42 (1938).

Nature of the Tryptophanase Complex

IN a previous communication[1] we described the preparation of a cell-free extract of tryptophanase from *Esch. coli* and its resolution into a coenzyme fraction and an apoenzyme.

The effect of various inhibitors was studied, as summarized below, and afforded information as to possible components of the enzyme complex.

Mepacrine. The inhibitory effect of mepacrine on the growth and tryptophanase activity of *Esch. coli* has already been announced[2] by Dawson, and this inhibition is antagonized by riboflavin.

Cyanide. *M*/50 potassium cyanide produces complete inhibition for 2 hr. and 93 per cent inhibition up to 18 hr.

Sodium Azide. A concentration of *M*/100 produces 50 per cent inhibition at 30 min.

Benzamide. *M*/1,000 produces 50 per cent inhibition, and this can be nullified by the addition of nicotinic acid.

Carbonyl Inhibitors. Hydrazine and hydroxylamine both give complete inhibition over the period of an hour, down to concentration *M*/1,000. Semicarbazide inhibits to 64 per cent at 30 min. with concentration *M*/100.

Dimedon is without effect on tryptophanase activity[6].

Carbon Monoxide. Produces 25 per cent inhibition at 30 min.

Hydrogen Sulphide. Produces 28 per cent inhibition at 30 min.

Sulphanilamide. (*a*) In culture. Complete bacteriostasis and hence non-production of tryptophanase at concentration *M*/43 (4 mgm./ml.). Using tenth dilutions, there was complete bacteriostasis at 24 hr. down to concentration *M*/4300 (that is, 40 μgm./ml.). (*b*) Viable washed cells. Sulphanilamide has no effect on preformed tryptophanase.

British Anti-Lewisite (*B.A.L.*), 2 : 3 dimercaptopropanol. At concentrations of *M*/10 and *M*/20 gives complete inhibition for 60 min., this effect decreasing with concentration until it is not manifest at all at *M*/1,000.

Effect of Verdoperoxidase. A preparation of verdoperoxidase from leucocytes was obtained by the method of Kjell Agner[4]. Although not a very active specimen, pronounced stimulation of tryptophanase activity was recorded. Catalase and polyphenol-oxidase have both been found to be absent from our extract.

The dialysate from cell-free tryptophanase has been examined spectrophotometrically, and the type of absorption curve obtained corresponded most closely to that of pyridoxal phosphate. Spectrochemical investigation of an unpurified sample of apoenzyme revealed the presence of iron, but not of copper. A microbiological assay of both dialysate and apoenzyme has also been performed, using *Lactobacillus casei E*, and riboflavin has been shown to be present in both.

Reconstitution of Tryptophanase. Using inactive apoenzyme, the various possible coenzyme factors were added in turn and the effect noted. In this way we have been able to show that pyridoxal phosphate, riboflavin and diphosphopyridine nucleotide are each capable of reactivating the apoenzyme; stronger activation is obtained with pyridoxal phosphate plus diphosphopyridine nucleotide and with riboflavin plus the nucleotide, whereas maximum effect is obtained by the addition of all three.

Discussion. The study of the effect of various inhibitors on the activity of tryptophanase initially provided strong presumptive evidence for the nature of the enzyme complex. The mepacrine inhibition and its antagonism by riboflavin gave indication of the functioning of flavoprotein in the complex, this being substantiated by the subsequent identification of riboflavin as a coenzyme factor. The effect of cyanide, hydrogen sulphide and carbon monoxide suggests that a cytochrome-type of system is operating, though it is known from the work of Keilin and Harpley[5] that cytochrome *c* and cytochrome oxidase are absent from *coli*, and also that bands *b* and *c* of normal cytochrome are replaced by one band which lies at 560 mμ and which represents the α-band of non-autoxidizable hæmochromogen component b_1.

A component containing the aldehyde or carbonyl grouping seemed likely from the way in which characteristic carbonyl reagents inhibited tryptophanase activity, and this has been reconciled with the presence of pyridoxal phosphate. In a similar manner the inhibition produced by benzamide, and antagonized by nicotinic acid, could be related to interference with a pyridino component such as diphosphopyridine nucleotide.

The effect of verdoperoxidase is of considerable interest. It has been suggested by Keilin[6] and Kuhn[7] that verdoperoxidase might be considered as more or less modified cytochrome-*a* derivatives. In view of absence of the cytochrome-*c* – cytochrome oxidase system, the marked increase in production of indole from tryptophane by our cell-free enzyme system in the presence of verdoperoxidase is of significance. Since *B.A.L.* is an inhibitor of metal-containing enzymes, as shown by Webb and Van Heyningen[8], this is compatible with the presence of an iron-containing system such as verdoperoxidase.

We should like to express our gratitude to Dr. E. F. Gale for a gift of pyridoxal phosphate, to Prof. R. A. Peters for *B.A.L.*, and to the Medical Research Council for a grant-in-aid.

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A Copepod Parasite of the Mussel New to the British Fauna

Mytilicola intestinalis is a worm-like copepod first found in 1902 by Steuer[1] in the intestine of the mussel *Mytilus galloprovincialis* from the Gulf of Trieste; since then, there have been a number of other records both from this mussel and *M. edulis*[2]. All these were from the Mediterranean area; but in 1939, Caspers[3] found it in mussels from the Bremerhaven–Cuxhaven area of the German North Sea coast, and, in February 1946, I found that mussels from the mouth of the River Blyth, Northumberland, were parasitized. More than 90 per cent of the Blyth mussels examined were found to be infected; in one case, 18 specimens were obtained from a single host.

All the records seem to have been obtained from estuarine zones: Caspers found, in his area, that while mussels from the estuaries were heavily infected, those from neighbouring purely marine zones were completely free: in the present case, mussels from Holy Island, the only purely marine bed on the Northumberland coast, were found to be uninfected. I hope to examine mussels from other estuaries in this area in due course.

Where the parasite was present, Caspers found that most mussels were infected, often heavily—he found 14 specimens in a single host. Finding it hard to believe that such a heavy infestation could have occurred in a short space of time, he considers that previously the parasite must have been overlooked. It is difficult to believe that the parasite could have been overlooked in the present case. Mussels from the Blyth have long been used in this Department as experimental material, often as a source of crystalline styles; as the parasite is quite large, adults being more than 1 cm. long, and fairly obvious because of their hæmoglobin, the search for the styles should have revealed their presence. But it would be very interesting to know whether, in fact, the parasite is a recent arrival to Great Britain; know-

ledge of its presence and, equally important, its absence, from estuarine mussels of other parts of the country would be invaluable, and I would be very grateful for information on this point.

The parasite should be very useful for teaching and other purposes, for the ease with which living *Mytilus* can be sent through the post means that, probably for the first time, a living parasitic copepod will be easily available to inland laboratories; mussels from the Blyth may be obtained from the Dove Marine Laboratory, Cullercoats, Northumberland.

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March 11.

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Copper in Diatoms

WORK undertaken in this Laboratory suggests that certain species of diatoms, which are the normal constituents of the slime film which forms upon a submerged surface in marine waters, contain copper, far in excess of the amount usually considered lethal for unicellular Algæ. (Half to one part per million is usually sufficient to remove algal growths from reservoirs.) Large colonies of marine diatoms were gathered freshly during the spring maximum of 1946, from a raft located in Chichester Harbour. Sixteen samples were examined: Nos. 1–12 inclusive were species which live in frondose colonies of mucous filaments, 5–10 cm. in length; samples Nos. 13–16 inclusive were species which grow either upon mucous stalks or embedded within a flat film.

After collection, the material was examined carefully and sorted into monotypic samples, care being taken to remove any contaminants such as filamentous seaweeds. The selected material was washed several times with filtered sea water, and examined for copper, using sodium diethyldithiocarbamate as an indicator. All samples gave a positive reaction, while samples 3–11 were submitted further to a quantitative estimation. The quantitative determination of copper was effected by the use of the absorptiometer method described by Haywood and Wood[1], with some special modifications. The selected material was washed free from salt and dried in a vacuum desiccator for 48 hours. Weighed portions of 0·5 gm. were wet-ashed; ammonium citrate was added in order to inhibit any iron that might be present, and strong solution of ammonia added, sufficient to produce an alkaline reaction. The mixture was then filtered to remove the siliceous skeletons of the diatoms, and the volume adjusted. Sodium diethyldithiocarbamate was added to a measured quantity of the mixture, which was allowed to stand for 15 minutes. The copper complex developed a yellow coloration, which was extracted by shaking with carbon tetrachloride, and estimated on a Hilger 'Spekker' absorptiometer.

The results showed that the diatoms contained from 31 to 164 parts per million of copper (weight/weight). The copper content of the sea water in which the diatoms lived was 0·007 mgm. per litre (7 parts per thousand million). It is not known in which form the copper is contained, but it is likely that it forms either an additive compound with the protein or alginin molecule within the diatom cell, and is thrown down as a coagulate or precipitate, or that it plays a functional part in the chromatophores.

Evidence from work upon cultures of diatoms without their siliceous frustules[2] indicates that the organisms can tolerate copper far in excess of that allowed by the range of solubility of copper in sea water of *p*H 7·92–8·2, which probably does not exceed 0·5 parts per million. It appears that the diatom forming so large a part of the slime which develops upon an underwater surface may be considered as a potential reservoir of copper, and in this way may play an important part in preventing the settlement of other and more sensitive fouling organisms.

Acknowledgment is made to the Board of Admiralty for permission to publish the foregoing work, which forms part of a general investigation in progress in this Laboratory on the anti-fouling problem relating to ships.

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The New Lava from Hekla

ON April 10 I received from Dr. Jóhannes Áskelsson of Reykjavik a specimen of the new lava from Hekla. Dr. Áskelsson states that the eruption began on March 29 at 7 a.m. (Icelandic time), and several lava streams began to flow in different directions. The specimen he sent was taken from the surface of the moving lava of a stream flowing east from the northern end of the Hekla ridge. It is a typical *aa* or block lava.

The rock is a dead black, highly slaggy basalt in which a few fresh white feldspars are entangled. In thin section the bulk of the rock turns out to be a brownish-black glass holding numerous swallow-tailed feldspar microlites, a few micro-phenocrysts of labradorite (Ab_1An_1), and still fewer of pyroxene and olivine.

This lava is identical with previous flows from Hekla, as I have ascertained by direct comparison with material collected by Sir George Steuart Mackenzie in 1810[1], which is preserved in the Hunterian Museum of the University of Glasgow. It is also identical with the Selsundhraun (*hraun*, Icel. = lava), a Recent flow 10 km. south-west of Hekla, of which I possess an unpublished analysis. This analysis agrees very closely with H. S. Washington's analysis of a Hekla lava from Nafrholt[2], and with Recent lavas from the Vatnajökull region[3]. All these magmas are slightly over-saturated with silica notwithstanding the early crystallization of a little olivine. It may therefore be concluded that the Recent basalt lavas of Iceland are very uniform in composition, and that there has been little or no change in that respect during the historical period.

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April 22.

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RADIO AIDS TO MARINE NAVIGATION

ONE of the earliest applications of radio wave transmission was the introduction of a service whereby ships could be informed of their position under conditions in which ordinary visual observations or dead reckoning were not very reliable. For many years past, radio direction-finding stations on shore have supplied bearings to ships making special signals for the purpose; while many forms of direction-finder suitable for installation in ships have also been available, and could be used for observing the bearings of fixed radio beacons, which can easily be identified by the simple code signals emitted at regular intervals. During the past seven years, the growth and development of radio technique has been so rapid and so extensive that not only has a great deal of advance been made in the field of radio direction-finding as such, but also there has been devised and developed a number of alternative systems of using radio waves for fixing the position of a ship, whether it be in the open sea, near a coast or approaching a harbour. There are, in fact, so many possible systems of radio aids to marine navigation that it has become quite a difficult problem to decide which are the best or most appropriate for various applications. In order to reduce the number and variety of equipments to be carried by ships navigating in various parts of the world, it is clearly desirable that there should be some measure of international agreement on the matter.

It was with the view of providing scope for a full discussion of the value of these radio navigational aids, and of discovering to what extent they meet the requirements of the navigator and shipowner, that the Ministry of Transport organised an international meeting in London in May 1946 (see *Nature*, 157, 689; 1946). The meeting was attended by some 120 delegates from twenty-three different countries, and a complete record of the proceedings of the meeting with its many lectures, demonstrations and visits has recently been compiled in two volumes by the Ministry of Transport and published by H.M. Stationery Office*.

The first volume provides a record of the proceedings of the conference with a full report of the discussions that followed the introductory lectures on the various systems, these lectures being given chiefly by the British naval officers and Government scientific workers who had been closely associated with the developments described.

The second volume contains the full text of the scientific and technical documents presented at the meeting, and comprises, in effect, a very full and up-to-date handbook dealing with the whole problem of marine navigation by means of radio transmission and reception. After introductory chapters on the needs of the mariner for navigational aids, and on radio wave propagation as it affects them, the volume goes on to examine in detail all the radio navigational aids in existence or under development. One section deals with all aspects of radio direction finding, both from ship and from shore, and including the different types of radio beacon. Another section covers hyperbolic systems of navigation, including Loran, Gee, Decca and other names familiar to many in the Services during the War. A large section is devoted to marine radar in all its forms, as a ship-borne instrument, as a shore installation for harbour supervision and in the form of radar beacons. This section also includes a specification for a ship-borne radar set, drawn up by combining a knowledge of the user's needs with a knowledge of the technical possibilities. This should prove of great value to the radar manufacturer and the shipowner, because both will know that a set conforming to this specification will be in every way satisfactory.

The development of transmitting compasses for association with radio navigational aids is dealt with, as is also the question of the provision of special charts in order to facilitate the work of the navigator in using the various aids. In the later portions of the volume an appreciation, with considerable technical detail, is given of the various devices discussed, and an important chapter speculates on the probable future trends of development.

This whole volume, which is well illustrated with diagrams and photographs, is essentially technical, and it contains a large amount of information unobtainable anywhere else. It will present many with their first picture of the far-reaching developments in radio navigational aids as a result of the War, and of the application of these developments to the safer and more efficient operation of ships at sea. It should prove of wide interest, and invaluable as a text-book to all who are in any way concerned with radio aids to navigation.

The publication of these two volumes is very opportune, and was in good time to pave the way for the continuation of the discussions at the recent international meeting in the United States of America.

* International Meeting on Radio Aids to Marine Navigation, May 1946. Vol. 1. Record of the Meeting and Demonstrations. 2s. 6d. net. Vol. 2. Radio Navigation: Radar and Position Fixing Systems for Use in Marine Navigation. 5s. net. (London: H.M. Stationery Office, 1946.)

ROLE OF STARCH IN LIGHT-INDUCED STOMATAL MOVEMENT, AND A NEW REAGENT FOR STAINING STOMATAL STARCH

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THE mechanism of the movement of stomatal guard cells in response to the stimulus of light, although under investigation for nearly a century, is still in doubt. The classical view[1] that such movements are due to changes of turgor has received support from many workers, who have found by plasmolytic methods that with stomatal opening the osmotic pressure in the guard cells increases[2–6]. More recently, the possible collaboration of a 'wall mechanism' in opening the stomata of *Cyclamen* and *Tradescantia* has been disproved[7], so that a turgor mechanism alone must be concerned; but how the changes in turgor are produced is still uncertain. Mainly owing to the work of Lloyd[8], Hagen[9], Loftfield[10] and Sayre[6] it is very generally accepted that they are due to hydrolysis or condensation of starch in the guard cells, probably brought about by enzyme action governed by *p*H changes in response to light. A careful examination of these and other relevant

papers, however, shows that nearly all the evidence for such a mechanism is based on the observation of diurnal changes in starch content and stomatal aperture under natural conditions. These observations leave little doubt that, under such conditions, pore size and starch content are to a large extent, though by no means completely, negatively correlated. A similar inverse relation is shown where change of aperture is experimentally induced by altering the water relations of the leaf[2], or by immersing detached pieces of leaf or epidermis in various solutions[11–14]; but such data are not necessarily relevant to the problem of a light response. Where stomatal movement has been experimentally induced by changes of lighting conditions, at other than the natural times, the evidence for a correlation between starch content and stomatal aperture is not convincing[2,15]. The correlation of diurnal trends is an unsafe basis for a causal theory, especially in this case, since it has been shown that in cherry laurel[16] and *Pelargonium*[17,18] there is a diurnal rhythm of stomatal movement even under conditions of constant illumination. The diurnal rhythm of stomatal starch, which has not been shown to be due to light, may well provide the motive power for such autonomous stomatal movements.

Much of the uncertainty as to the relation between stomatal aperture and starch content arises from difficulties of estimation. Both stomatal apertures and guard cell starch show great variation between leaves and even on the same part of a single leaf. The measurement (usually by Lloyd's[8] method) of a sufficient number of stomata to give a satisfactory mean is tedious and seldom attempted, and errors in sampling procedure are probably common; for starch content no quantitative measure has been devised or seems possible, and subjective errors must be considerable. Furthermore, previous investigators have laboured under the great disadvantage of being unable to observe both aperture and starch simultaneously in the same stomata, because the aqueous iodine–potassium-iodide reagent used to stain the starch causes stomatal closure. This source of inaccuracy has now been overcome, for I have found that the reagent described below stains the starch very satisfactorily and causes no stomatal closure even in strips of epidermis that have been in absolute alcohol for a few days only. It has a very high refractive index, and excellent images may be obtained, either for visual work or photomicrography, by mounting the material in the reagent. The reagent is made by dissolving 2·5 gm. of iodine in 100 c.c. of phenol, containing the minimum amount of water necessary to make it liquid at room temperature and an excess of potassium iodide. The water-in-phenol solution may be conveniently obtained by leaving the stopper out of a bottle of pure phenol. The use of this reagent has made it possible to reduce subjective errors since photomicrographs showing both aperture and starch content may be compared. Photomicrographs of *Pelargonium* stomata have been taken which show approximately the same average starch content with relatively wide and relatively narrow apertures, in epidermal strips taken at the same time of day under conditions of light and darkness respectively. Here the possibility of diurnal rhythms in starch and aperture being concerned is eliminated. Photomicrographs from other experiments give evidence of increases in starch content without appreciable change of aperture, and even of decreased starch with decreased aperture.

Although the comparison of such photomicrographs reduces subjective errors and their publication will enable other workers to judge for themselves, the difficulties of taking representative samples and estimating mean values remain. If stomatal movement can be induced by light in the complete absence of starch, the matter rests on a more secure basis. I have been unable to find any starch (or chloroplasts) in the guard cells of onion stomata (*Allium cepa*, L.), either open or closed, thus confirming the observations of Parkin[19]. The investigations of Loftfield[10], using Lloyd's[8] method, showed that under natural conditions the stomata of the onion were motile; but again an autonomous diurnal rhythm might have been concerned or a response to some external factor other than light. It has now been shown by porometer experiments that onion stomata respond in the normal way to light, and therefore this species at least has a light response which does not depend upon a starch ⇌ sugar mechanism.

In view of the very diverse character of the numerous stimuli to which stomata respond it seems improbable that a unique mechanism is concerned, except to the extent that all responses must be due to turgor changes, and each type of stimulus will require separate investigation. For the present, only the response to light is under consideration, and here the evidence for a starch ⇌ sugar mechanism seems inadequate.

This work will be published in detail elsewhere.

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THE INVERNESS-SHIRE EARTHQUAKE OF DECEMBER 25, 1946

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At about 17 hr. 2 min. (G.M.T.) on Christmas Day, 1946, an earthquake of maximum intensity VI (C. Davidson scale), accompanied by sounds, originated close to Spean Bridge in Inverness-shire, and was felt throughout much of central Scotland. Associated with it were at least two fore-shocks and one after-shock.

Postal reports received in response to appeals through newspapers, questionnaire-cards and radio broadcasts show that the disturbed area included the eight shires of Ross, Inverness, Perth, Argyll, Edinburgh, Clackmannan, Stirling and Renfrew. The region enclosed by a first approximation to isoseismal IV (C. Davison scale) is about 3,500 square miles. Extreme points from which such reports have been

received, to date, are Muir of Ord in the north, Glasgow in the south, Edinburgh in the east and Tobermory, Isle of Mull, in the west.

The fore-shock of December 24, 1946, associated with the main quake, was felt not only in Inverness-shire and Argyll, but also as far south as Fenwick, Ayrshire.

The epicentre of this earthquake lies in the Inverness–Oban seismic zone, which includes the fracture-system of the Great Glen fault. Interest attaches to the fact that the recent tremors indicate stress-relief in a part of this zone where only one other earthquake of the same order of intensity has been recorded hitherto[1]. This latter was noticed at Gairlochy, Spean Bridge and Roy Bridge, over a period of six seconds, between 22 hr. and 23 hr. (G.M.T.) on August 22, 1924, when it attained a maximum intensity of IV (C. Davison scale).

Regarding the most recent activities at foci in the same zone, adjacent to Spean Bridge, records indicate that tremors originated near Inverness in September[2] and October 1901[3] and near Oban in both December 1925 and May 1941. Thus, between 1901 and 1947 foci have been active in the sequence: Inverness, Spean Bridge, Oban, Oban, Spean Bridge, suggesting a return of stress-relief to the central region of the zone after previous manifestations of this relief in the north, centre and south of the zone, respectively.

Times and durations noted in the epicentral region lead to the conclusion that the quake of December 25, 1946, began about 17 hr. 2 min. (G.M.T.) as a rumbling sound of low pitch which continued for about two seconds. This was followed by three sharp tremors, occurring over a period of about three seconds, the first of which exceeded the intensity of either of the others. The last tremor was followed by a further rumbling sound which became inaudible after about three seconds.

Close to the epicentre, effects of the three main tremors were compared to those of sudden explosions, such as the detonations of hand grenades. In a surrounding zone only one tremor was noticed, generally preceded, but not always followed, by a sound. Beyond this zone a weak tremor was felt, usually unaccompanied by any sound.

Some observers described sounds heard about the epicentre as being similar to the deep rumbling of a heavy vehicle passing over a bridge, or thunder, or gunfire at a distance. Others compared them to the roaring of wind, or to the noise of a train in a tunnel. At places remote from the epicentre, the sound was said to possess a harsh, rasping quality.

The intensity of this earthquake appears to have exceeded that of August 22, 1924, in the same locality (namely, IV (C. Davison scale)), for on this recent occasion not only were the chairs of several seated observers noticeably moved at Gairlochy and Spean Bridge, but also a plaster ceiling was thrown down in Achnacarry at the east end of Loch Arkaig; a chimney-pot dislodged from a house at the north-east end of Loch Laggan; two heavy shop-safes moved in Fort William, and windows, doors and crockery rattled at many places in the area. These, and similar phenomena, are consistent with a maximum intensity of about VI (C. Davison scale). Further, the position and form of the central disturbed area, and distribution of intensities within it, suggest a close association of this earthquake with the Great Glen fault-system. On the other hand, present information suggests there was no significant sympathetic movement in the Highland Boundary fault-system at or about the time when these recent Spean Bridge disturbances took place.

A weak fore-shock connected with this earthquake appears to have occurred at about 17 hr. 20 min. (G.M.T.) on November 19, 1946, and a second one close to 24 hr. (G.M.T.) on December 23, 1946. The latter, which was noticed in Inverness-shire, Argyll and north Ayrshire, consisted of two tremors lasting about four seconds and three seconds respectively, separated by an interval of about two seconds.

The after-shock of January 5, 1947, would seem to have taken place at about 09 hr. 35 min. (G.M.T.), when a slight rumble was heard in West Glen Roy and Glen Spean, having a duration of about three seconds.

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INDUSTRY AND RESEARCH

CONFERENCE AT BIRMINGHAM

THE first of the regional conferences on "Industry and Research" sponsored by the Federation of British Industries was held at Birmingham on March 25. The morning session, over which Sir Ernest Canning, vice-president of the Federation, presided, was devoted to "Research and Economic Recovery", and Sir Ernest, in opening the Conference, emphasized the vital importance of research, not merely in the evolution of new materials, processes and products, but also in the improvement of existing processes and products. He pointed out that it is a vital factor in promoting the more effective use of materials, labour and power, thus saving coal and other fuels; and while in the short term we must all work harder, the only long-term method of restoring our pre-war standard of living lies in the persistent application of the scientific method and scientific advances to our industrial technique and life. We cannot equip ourselves for the highly competitive struggle in the world's markets which in two or three years will follow the sellers' market if we postpone the prosecution of industrial research until the time when the application of its results is essential to strengthen our competitive power.

In his paper on "Industrial Research and the National Economy", Sir William Larke commented on the document "Economic Survey for 1947" that in industry alone resides the power of making good the shortages and the responsibility of obtaining maximum production from the resources of fuel, raw materials and man-power which the Government is largely responsible for making available for industry. He urged that the scientific method must be applied throughout, starting at the level of the boards of directors. Sir William referred particularly to the possibilities in the saving of fuel by technical investigation and control, the economies in the use of raw materials and the reduction of waste often achieved by technical research, and the contribution of technological investigation of processes and machine operation to the increase in output per man-year. These are short-term measures for immediate application, but the long-term measures, including fundamental research, are in some ways an even more important factor. Sir William believes that the technical colleges have a more important part to

play than in the past, and he emphasized the need for a spirit of inquiry and the development of research-mindedness as a national characteristic.

In the second paper at this session, Dr. J. W. Jenkin dealt with Midland industries and their research needs. These industries are exceedingly varied and multifarious; but there are some common factors, and whether the work be mechanical or scientific, real progress can only come from a ruthlessly objective study of all relevant facts and creative thinking to find relations between them and to devise the crucial experiments. There appears to be a need for a closer link between the scientific work characterizing the newer industries and the engineering inventiveness common in the older. This can often be supplied by making the same persons responsible both for the research results and their translation into practice. The bridging of the gap between the discovery and its commercial exploitation, the development stage, should not be left as a spare-time activity of those primarily responsible for administration, production or sales. Men are needed with wide sympathies to direct research away from over-emphasis on a restricted field of technology into closer liaison with development.

Sir Edward Appleton presided over the second session of the Conference, which dealt with industrial research in the Midlands. He commented on the increasing readiness of many scientific workers in universities and technical colleges to place their knowledge at the disposal of industry, but at the same time thought that the encouragement of co-operative action through the research associations is the most effective means of supplying the particular scientific knowledge which industry requires. Mr. F. G. W. King, technical director of the Dunlop Rubber Co., Ltd., contributed a well-documented paper on Midland research organisations, activities and facilities, in which he suggested that since most of the industrial research in this large and varied region is carried out in the laboratories of the large firms, although related contacts spread all over the country, investigation of methods of increasing productivity, particularly the skilled study of flow production, and close co-operation between research units and their related groups in firms, research associations and universities are required, in addition to further research. Such co-operation should be facilitated by fuller documentation of the broad fields of the research, to give a general idea of the problems studied, and he suggested that the research secretariat of the Federation of British Industries might help in the organisation of such documentation. Research, moreover, would only be fully effective if its results were known and appreciated by other experts and skilled workers in the industry. Appendixes to Mr. King's paper include an analysis of industries in the Birmingham region, and lists of industrial research in progress in technical colleges and universities, either in the region or outside the region, when specially related to its industries. The information relating to the universities was taken mainly from the "Notes on Current Scientific Researches in the United Kingdom" prepared for the Royal Society Empire Scientific Conference last year.

The concluding paper of the Conference, by Mr. J. C. Pearce, dealt with the smaller Midland firm and its application of research. Mr. Pearce suggested that the firm not large enough to provide one full-time or part-time technical man to act in liaison with outside developments should treat its research association as a source of information and apply for information as and when required. It should give the staff of the Association opportunities of assessing the nature of its work and problems so that replies can be suited to its ability to give effect to them. The research associations should treat this information from individual firms as strictly confidential, but use it to build up that part of the current research programme dealing with experimental work directed towards the solution of specific problems common to the industry as a whole or to sections of it. Mr. Pearce believes that the major functions of a research association, namely, the application of new knowledge through development and the dissemination of knowledge by intelligence activities, has been least satisfactorily solved.

In the discussion Mr. L. E. Lines, repudiating the suggestion that young industrial scientific workers should be excused military service, said that Great Britain is suffering from seeking too much security. Dr. Quarrel pointed out that this year we shall have only one fifth of the number of scientific recruits which was available to industry in 1938, and only one half of the average number for the war years. Sir William Akers, in summing up, said that some of the observations indicated that in certain directions planning by the Government has been very incomplete, and asked whether we should not now put all the technically and industrially fit people into the economic war.

OIL PLANTS IN EAST AFRICA

THE plan for mechanized production of ground-nuts in East Africa described in the recent White Paper (Cmd. 7030) and the inherent importance of all oleaginous crops to-day give added interest to an informative and well-documented review of oil plants in East Africa by A. Glendon Hill, director of the East African Agricultural Research Institute (*E. Afr. Agric. J.*, **12**, 140; 1947). It deals with ground-nuts, sesame and sunflower.

Ground-nuts. One of the most valuable of oil plants, with an oil content of nearly 50 per cent in the shelled nuts, it is widely grown by natives in East Africa, mainly for their own food; though it has not hitherto attracted the European farmer to any extent. In addition to oil, the nuts are rich in protein (about 30 per cent), so that after extraction of the oil the press cake forms a valuable cattle food. Mr. Glendon Hill thinks this cake may in future be largely used for manufacture of artificial wool such as 'Ardil'. The main ground-nut areas of East Africa are the western, central, lake and southern provinces of Tanganyika, the eastern province of Uganda, and the Nyanza and coast provinces of Kenya. Only a small proportion of the crop is exported—21,000 tons in 1942. In 1936, 290,000 acres in Tanganyika and 167,000 acres in Uganda were under ground-nuts; and in 1944 it was estimated there were 400,000 native growers in Tanganyika.

Types and varieties, soils and manures, cultivation, harvesting, diseases and pests, and crop economics are described. There are a great number of varieties, which can be grouped into three main types, of which the 'bunch' or 'upright' is the most desirable, as exemplified by Virginia Bunch, which is early, drought-resistant, gives good yield and oil content,

but has hard shell. Spanish Bunch is even earlier, but with smaller yield. The ground-nut responds markedly to plant selection, which has been done in East Africa for some years with occasional notable success; for example, in evolving wilt-resistant strains. As it is not a self-fertile plant, selection and isolation of new strains is comparatively easy. Selection has been mostly directed to high yield and kernel percentage, with resistance to rosette disease; but not, so far as is known, to evenness in ripening—lack of which often causes serious trouble in harvesting—or to long dormancy and high oil content. In Uganda, bunch types are encouraged, but selection is proceeding with creeping types owing to their resistance to locusts. Selection has resulted in higher yielding varieties in some areas; but owing to the varying behaviour of different selections depending on season, final choice is difficult. In Nigeria, selection over five years resulted in 25 per cent yield increase in bunch type and 16 per cent in creeping type. Work with existing East African types is thought to be better than with imported varieties.

The best soils are light, sandy, well-drained loams, not too rich in organic matter; addition of lime and phosphate is often beneficial. The ground-nut fits in well with several different rotations, including cotton and maize. Fairly close spacing to keep the ground well covered is important, and weeds are often allowed to grow for this purpose. Yields per acre vary enormously according to conditions: from 200 to 2,200 lb. unshelled on native farms, though the average is nearer 600 lb., which is slightly less than the yield obtained in the United States. Mechanized farming in Queensland gives 3,600 lb. unshelled.

Sesame (simsim, ufuta, gingelly, bene, or til) has also high oil content, usually about 50 per cent, but sometimes much higher, with about 20 per cent protein and 18 per cent carbohydrate. Calcium content in the undecorticated product is remarkably high (1 per cent, mostly in the seed-coat), while phosphorus is 0·7 per cent. The main sesame areas in East Africa are: southern province of Tanganyika, northern province of Uganda, and Nyanza province of Kenya. It is mostly grown by native farmers for their own use, and the average yield is 350–400 lb. per acre. Care has to be taken not to contaminate with wild sesame (*S. radiatum* or *Ufuta mwitu*), which contains a substance toxic to cattle. There are many varieties, but the principal types are white and black. In Uganda, selection has aimed at high-yielding white-seed types for export, and has resulted in some improvement; as also in Tanganyika. Soils and climate, cultivation, harvesting, storage, pests, etc., are described. From the economic point of view, the yield from sesame is only about one third that of ground-nuts, and it is a major crop only where soils are sticky and make ground-nut harvesting expensive. It does not interest European farmers greatly.

Sunflower. As is well known, this crop covers vast areas in the U.S.S.R., and to a less degree in the Argentine, the Balkans, and China. It is not grown to any large extent in Africa. The best known in the past have been the giant types with heads 12–22 in. across, but easily sensitive obviously to wind and rain. A dwarf type has been introduced in Britain and elsewhere, such as the Pole Star, Southern Cross, Jupiter, and Mars. Attempts are being made to obtain seed of these varieties for trial in East Africa; but whether it is economically feasible there depends on world prices. Some notes on cultivation, etc., are given.

CHANK MARKING EXPERIMENTS AT TUTICORIN

FOR the purpose of ascertaining the migrations and growth-rate of the chank, marking experiments were begun in 1931 by the Madras Fisheries Department*. Since then about 5,000 chanks have been marked and liberated on the chank beds of Tuticorin. It was thought that there might be a migration of chanks from those beds to the Ceylon beds on the other side of the Gulf of Mannar. The experiments have shown that such migrations do not take place; but there are movements of chanks from one bed to another in the immediate vicinity. The greatest distance covered by any marked chank was nine miles.

There is marked variation in observed rates of growth, some specimens showing very little increase over long periods, while others have grown as much as 23 mm. in length in 23 months. The reason for this disparity is not known, but the suggestion is made that it may be due to variations in hydrological and other conditions on the different beds. This is a fairly safe guess, but it is no more than that. Much more work will have to be done and the data handled much more carefully and expertly before a sound knowledge of the bionomics of the chank can be acquired. It should not be necessary to state, for example, that of the 5,000 odd chanks that have been marked "only *about* 259 were recovered". Chanks are by no means minute animals, and the exact number recovered by the investigator must surely be known and should be recorded and reported upon with equal accuracy. In the absence of such accuracy little reliance can be placed upon any results obtained or conclusions reached.

Moreover, no scientific investigator should send out a paper in which only the local (common) name of the organism under investigation is given. Presumably the chank referred to in this paper is the gastropod *Turbinella pyrum*, Linn., but nowhere is this stated.

* Preliminary Study of the Chank Marking Experiments at Tuticorin. By K. Chidambaram and M. Mukandan Unny. A paper read before the Zoological Section of the Indian Science Congress, January 1947.

FORTHCOMING EVENTS

Monday, May 12

FARMERS' CLUB (at the Royal Empire Society, Craven Street, Strand, London, W.C.2), at 2.30 p.m.—Mr. Martin Jones: "Ley Farming and the Livestock Population".

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS (at the Institution of Electrical Engineers, Savoy Place, Victoria Embankment, London, W.C.2), at 5 p.m.—Mr. W. H. Leech: "The Work of the Sub-Marine Section during the War".

SOCIETY OF PUBLIC ANALYSTS AND OTHER ANALYTICAL CHEMISTS, BIOLOGICAL METHODS GROUP (in the West Hall, Royal Society of Medicine, 1 Wimpole Street, London, W.1), at 6 p.m.—Symposium on "The Production and Care of Laboratory Animals", Part 3. Dr. J. I. M. Jones and Dr. Eric C. Wood: "Housing"; General Discussion on all subjects.

Tuesday, May 13

ELECTRICAL ASSOCIATION FOR WOMEN (at the Connaught Rooms, Great Queen Street, London, W.C.2), at 10.30 a.m.—Fourteenth Annual General Meeting.

ZOOLOGICAL SOCIETY OF LONDON (at Regent's Park, London, N.W.8.), at 5 p.m.—Scientific Meeting.

INSTITUTION OF ELECTRICAL ENGINEERS, RADIO SECTION (at Savoy Place, Victoria Embankment, London, W.C.2), at 5.30 p.m.—Discussion on "Future Trend of Component Design for the Services" (to be opened by Dr. G. W. Sutton and Mr. E. M. Lee).

ILLUMINATING ENGINEERING SOCIETY (at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1), at 6 p.m.—Annual General Meeting; at 6.30 p.m.—Dr. N. A. Halbertsma: "International Relations in Illuminating Engineering".

SOCIETY OF INSTRUMENT TECHNOLOGY, NORTH-WEST SECTION (at the College of Technology, Manchester), at 7.15 p.m.—Annual General Meeting; Dr. J. Yule Bogue: "The Measurement of Non-Cyclical Biological Phenomena".

Wednesday, May 14

BRITISH GLACIOLOGICAL SOCIETY (in the Department of Geography, Downing Place, Cambridge), at 5 p.m.—Discussion on "Glaciological Research in the Antarctic".

GEOLOGICAL SOCIETY OF LONDON (at Burlington House, Piccadilly, London, W.1), at 5 p.m.—Scientific Papers.

ROYAL COLLEGE OF SURGEONS (at Lincoln's Inn Fields, London, W.C.2), at 5 p.m.—Prof. F. Wood Jones, F.R.S.: "The Hallmarks of Humanity" (Arris and Gale Lecture).

ROYAL METEOROLOGICAL SOCIETY (at 49 Cromwell Road, South Kensington, London, S.W.7), at 5 p.m.—Prof. C. Störmer: "Mother-of-Pearl Clouds".

ROYAL SOCIETY OF ARTS (at John Adam Street, Adelphi, London, W.C.2), at 5 p.m.—Mr. Alfred C. Bossom: "Economic Reconstruction, 8, Britain's Economic Future".

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE (at the Royal Institution, 21 Albemarle Street, London, W.1), at 5.30 p.m.—Prof. E. D. Adrian, O.M., F.R.S.: "The Sense of Smell" (Alexander Pedler Lecture).

INSTITUTION OF ELECTRICAL ENGINEERS, TRANSMISSION SECTION (at Savoy Place, Victoria Embankment, London, W.C.2), at 5.30 p.m.—Dr. Waldemar Borgquist: "Recent Research and Development Work in Sweden on High-Voltage A.C. and D.C. Power Transmission".

ROYAL STATISTICAL SOCIETY, NORTH-EASTERN GROUP OF THE INDUSTRIAL APPLICATIONS SECTION (at the Newcastle Chemical Industries Club, 18 Lovaine Place, Newcastle-upon-Tyne), at 6.30 p.m.—Mr. Glen Wortley: "The Use of Statistical Methods in Steel Production".

Wednesday, May 14—Friday, May 16

IRON AND STEEL INSTITUTE (at 4 Grosvenor Gardens, London, S.W.1).—Annual General Meeting.

Wednesday, May 14

At 10 a.m.—Symposium on "The Hardenability of Steel"; at 8.30 p.m. (at the Institution of Civil Engineers, Great George Street, London, S.W.1).—Dr. C. Sykes, F.R.S.: "Steels for Use at Elevated Temperatures" (Second Hatfield Memorial Lecture).

Thursday, May 15

At 9.55 a.m. (at the Institution of Civil Engineers).—General Meeting.

Friday, May 16

At 10.30 a.m. (at the Institution of Civil Engineers).—General Meeting.

Thursday, May 15

INSTITUTION OF MINING AND METALLURGY (at the Geological Society, Burlington House, Piccadilly, London, W.1), at 4 p.m.—Annual General Meeting: Prof. W. R. Jones: "Geographic Changes in Mineral Producing Centres" (Presidential Address).

ROYAL SOCIETY (at Burlington House, Piccadilly, London, W.1), at 4.30 p.m.—Prof. P. M. S. Blackett, F.R.S.: "The Magnetic Field of Massive Rotating Bodies".

CHEMICAL SOCIETY, SHEFFIELD SECTION (joint meeting with the SHEFFIELD UNIVERSITY CHEMICAL SOCIETY, in the Chemistry Lecture Theatre, The University, Sheffield), at 5.30 p.m.—Prof. J. B. Speakman: "Some Relationships between the Structure and Properties of Natural and Synthetic Fibres".

ROYAL STATISTICAL SOCIETY, TEES-SIDE SUB-GROUP OF THE INDUSTRIAL APPLICATIONS SECTION (at the Cleveland Scientific and Technical Institute, Corporation Road, Middlesbrough), at 6.30 p.m.—Mr. W. L. Stevens and Mr. J. T. Richardson: "Statistical Control and Factory Costs".

INSTITUTION OF STRUCTURAL ENGINEERS, LANCASHIRE AND CHESHIRE BRANCH (in the Reynolds Hall, College of Technology, Manchester), at 7 p.m.—Annual General Meeting.

ROYAL SOCIETY OF TROPICAL MEDICINE AND HYGIENE (at Manson House, 26 Portland Place, London, W.1), at 8 p.m.—Discussion on "Amœbiasis" (to be opened by Dr. C. M. Wenyon, F.R.S.).

Friday, May 16

BRITISH RHEOLOGISTS' CLUB (joint meeting with the CHEMICAL SOCIETY, at the Washington Singer Laboratories, University College of the South-West, Exeter), at 2.15 p.m.—Discussion on "The Chemistry and Rheology of Clay Systems" (to be opened by Dr. G. Nagelschmidt and Mr. H. H. Macey).

CHEMICAL SOCIETY, MANCHESTER SECTION (joint meeting with the LOCAL SECTIONS of the SOCIETY OF CHEMICAL INDUSTRY and the ROYAL INSTITUTE OF CHEMISTRY, in the Chemistry Lecture Theatre, The University, Manchester), at 6 p.m.—Dr. G. M. Dyson: "A New Notation for Organic Chemistry".

SHEFFIELD METALLURGICAL ASSOCIATION (joint meeting with the ROYAL INSTITUTE OF CHEMISTRY and the MICROCHEMISTRY GROUP of the SOCIETY OF PUBLIC ANALYSTS, in the Chemistry Lecture Theatre, The University, Western Bank, Sheffield), at 6 p.m.—Scientific Papers.

INSTITUTION OF ELECTRONICS, N.W. ENGLAND SECTION (in the Reynolds Hall, College of Technology, Manchester), at 6.45 p.m.—Dr. A. Levins: "Radar Navigation".

INSTITUTE OF ECONOMIC ENGINEERING (at Cowdray Hall, 1a Henrietta Place, London, W.1), at 7 p.m.—Mr. A. W. Willsmore: "Practical Problems of Production Control".

WOMEN'S ENGINEERING SOCIETY (at 35 Grosvenor Place, London, S.W.1), at 7 p.m.—"Women in Post-War Engineering".

APPOINTMENTS VACANT

APPLICATIONS are invited for the following appointments on or before the dates mentioned:

PASTURE RESEARCH OFFICER for Kenya—The Director of Recruitment (Colonial Service), Colonial Office, 15 Victoria Street, London, S.W.1 (May 17).

LECTURER IN NEUROLOGY at Manchester Royal Infirmary—The Registrar, The University, Manchester 13 (May 19).

LECTURER IN CHEMISTRY and a LECTURER IN BIOLOGY—The Clerk to the Governing Body, Battersea Polytechnic, London, S.W.11 (May 21).

BACTERIOLOGIST—The Secretary, Glasgow Royal Infirmary, 135 Buchanan Street, Glasgow, C.1 (May 22).

ASSISTANT LECTURER (Grade II) IN MECHANICAL ENGINEERING, ASSISTANT LECTURER (Grade III) IN CIVIL ENGINEERING, and ASSISTANT LECTURER (Grade III) IN FLUID MECHANICS—The Registrar, The University, Liverpool (May 23).

LECTURER or SENIOR LECTURER IN ELECTRO-TECHNICS—The Registrar, The University, Manchester 13 (May 24).

SENIOR CLINICAL PHOTOGRAPHER—The Secretary and Registrar, The University, Bristol (May 24).

LECTURER IN CIVIL ENGINEERING—The Secretary, Queen's University, Belfast (May 24).

ASSISTANT KEEPER IN ENTOMOLOGY in the Manchester Museum—The Registrar, The University, Manchester 13 (May 26).

ASSISTANT LECTURER (Grade III) IN THE DEPARTMENT OF GEOLOGY—The Registrar, The University, Liverpool (May 27).

CHIEF PHOTOGRAPHER—The House Governor, King's College Hospital, Denmark Hill, London, S.E.5 (May 30).

PROFESSIONAL OFFICERS IN THE VETERINARY BRANCH of the Department of Agriculture and Lands, Southern Rhodesia—The Secretary, Office of the High Commissioner for Southern Rhodesia, 429 Strand, London, W.C.2 (May 31).

ANALYTICAL CHEMIST, and a PHYSICAL CHEMIST, in the Senior Scientific Officer grade in the Chemical Research Laboratory of the Department of Scientific and Industrial Research—The Secretary, Civil Service Commission, 6 Burlington Gardens, London, W.1, quoting No. 1866 (May 31).

RESEARCH FELLOWSHIP IN PURE SCIENCE, and a RESEARCH FELLOWSHIP IN ARTS—The Secretary, University of Durham, 38 North Bailey, Durham (May 31).

SENIOR AND JUNIOR RESEARCH FELLOWSHIPS—The Director, Atomic Energy Research Establishment, Harwell, Didcot, Berks. (May 31).

LECTURER IN CIVIL ENGINEERING, a LECTURER IN MECHANICAL ENGINEERING, and a LECTURER IN ENGINEERING DRAWING AND DESIGN, in the University of Adelaide—The Secretary, Universities Bureau of the British Empire, 24 Gordon Square, London, W.C.1 (May 31).

RAMSAY MEMORIAL FELLOWSHIP for chemical research—The Joint Honorary Secretaries, Ramsay Memorial Fellowships Trust, University College, Gower Street, London, W.C.1 (May 31).

READER IN PATHOLOGY—The Secretary and Bursar, Royal Veterinary College and Hospital, Royal College Street, London, N.W.1 (May 31).

CURATOR and DEPUTY CURATOR for Horniman Museum, London Road, London, S.E.23, and a CURATOR for Geffrye Museum, Kingsland Road, London, E.2—The Education Officer (Estab. 2), County Hall, London, S.E.1 (May 31).

LECTURER IN THE DEPARTMENT OF BACTERIOLOGY—The Registrar, The University, Liverpool (May 31).

SENIOR ENTOMOLOGIST and ASSISTANT to carry out investigations into the control of midges in Scotland—The Secretary, Scientific Advisory Committee, Department of Health for Scotland, St. Andrew's House, Edinburgh 1 (May 31).

CHAIR OF PHYSIOLOGICAL CHEMISTRY, and an ASSISTANTSHIP IN ELECTRICAL ENGINEERING—The Secretary of the University Court, The University, Glasgow, W.2 (May 31).

ASSISTANT LECTURER (Grade III) IN THE DEPARTMENT OF GEOGRAPHY—The Secretary, University College, Gower Street, London, W.C.1 (May 31).

LECTURER and CHIEF ASSISTANT IN PUBLIC HEALTH—The Registrar, The University, Leeds 2 (May 31).

LEVERHULME STUDENTSHIPS IN CHEMICAL ENGINEERING—The Secretary, University College, Gower Street, London, W.C.1 (June 1).

COKE RESEARCH FELLOWSHIP—The Registrar, The University, Sheffield (June 1).

LECTURER IN BACTERIOLOGY in the Dental School—The Registrar, The University, Manchester 13 (June 2).

ASSISTANT LECTURER IN PHYSICS, and an ASSISTANT LECTURER IN MATHEMATICS—The Registrar, University College of South Wales, Cathays Park, Cardiff (June 8).

ASSISTANT CIVIL ENGINEERS for the Directorate General of Works—Under-Secretary of State (S.2(h)), Air Ministry, Cornwall House, Stamford Street, London, S.E.1.

ENGINEER (British) in the Recording Section of the Research Department of the B.B.C.—Engineering Establishment Officer, Broadcasting House, London W.1.

SENIOR ASSISTANT IN THE DEPARTMENT OF METALLURGY—The Principal, Central Technical College, Suffolk Street, Birmingham 1.

SENIOR LABORATORY STEWARD IN THE CHEMISTRY AND BIOLOGY DEPARTMENT—The Registrar, Municipal College, Portsmouth.

SENIOR TECHNICIAN IN THE DEPARTMENT OF ANATOMY—The Secretary, St. Mary's Hospital Medical School, London, W.2.

SENIOR TECHNICIAN IN THE PATHOLOGICAL AND BACTERIOLOGICAL LABORATORY—The Medical Superintendent, Dudley Road Hospital, Birmingham 18.

PHYSICAL CHEMIST to conduct research on corrosion problems—The Personnel Officer, British Iron and Steel Research Association, 11 Park Lane, London, W.1, quoting 'Chemistry Department'.

RESEARCH MANAGER, and CHEMISTS and PHYSICISTS on the research staff—The Director, Paint Research Station, Waldegrave Road, Teddington, Middx.